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SURFACE-DUCT SONAR MEASUREMENTS (SUDS I - 1972) PROPAGATION LOS--ETC(U)
APR 76 E R ANDERSON
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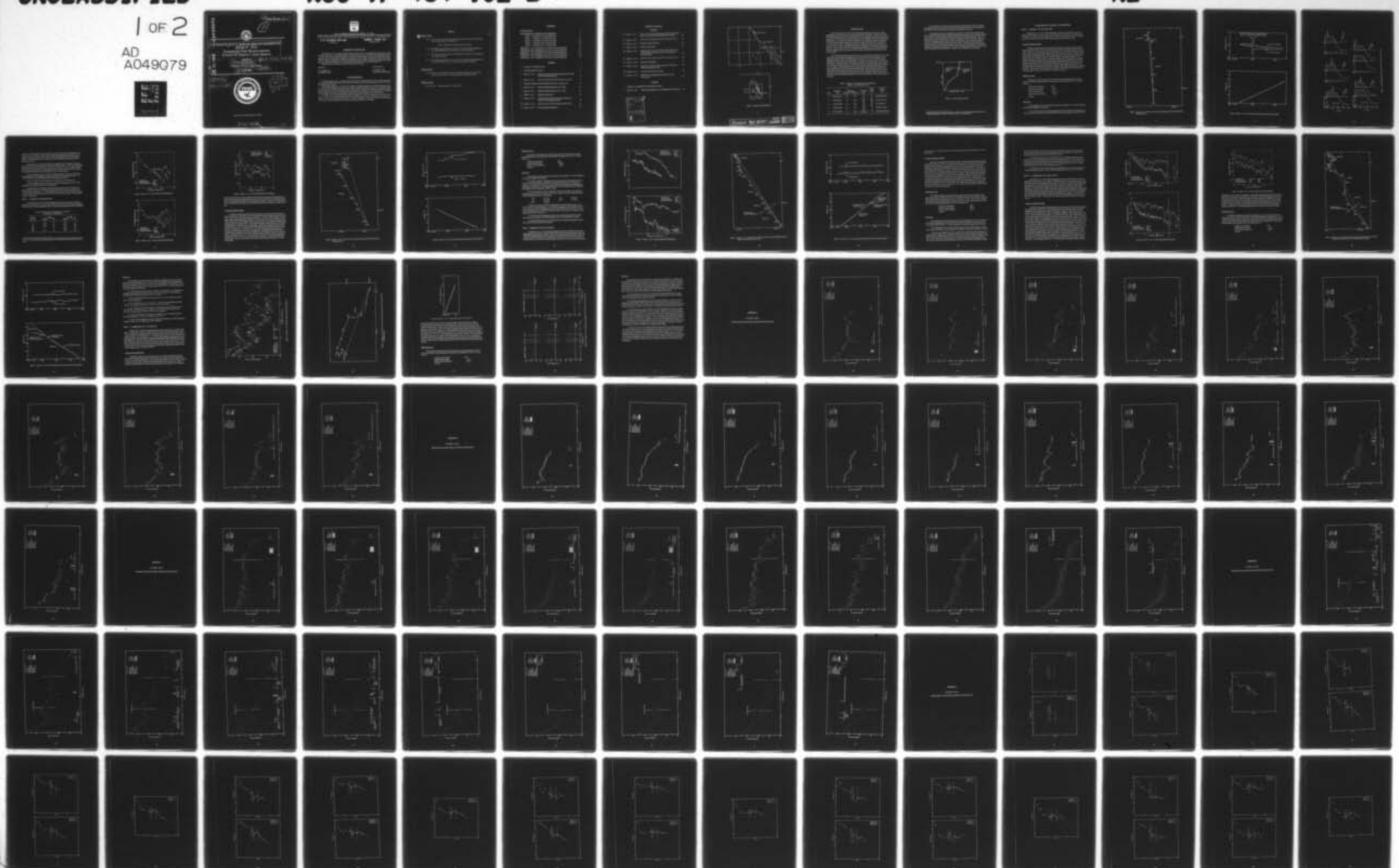

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SURFACE-DUCT SONAR MEASUREMENTS (SUDS I - 1972)

Propagation Loss Measurements. Volume II: Station 1 Data Report.

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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Commander

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Technical Director

ADMINISTRATIVE INFORMATION

During February 1972 the Naval Undersea Center conducted a series of 18 propagation loss experiments in three deep-water areas off the coast of California. These experiments are known as the SUrface Duct Sonar Measurements (SUDS I – 1972). This work was originally supported by the then Naval Ships Systems Command, Sonar Technology Division, PMS-302-4 and partly supported by the Office of Naval Research, code 102-OSC. The preparation of this report began in April 1973 under the sponsorship of the Naval Sea Systems Command, code 06H1-4, problem SF 52-552-602, task 19344. This report covers work from March 1971 to February 1976 and was approved for publication in April 1976.

Technical reviewers for this report were M. A. Pedersen and R. F. Hosmer.

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ACKNOWLEDGEMENTS

The SUDS I program was a coordinated and cooperative effort involving personnel from the Undersea Sciences and the Undersea Surveillance Departments. The program was basically an Acoustic Propagation Division project developed by H. P. Bucker and H. S. Aurand.

The Principal Investigator was J. Cummins. H.P. Bucker was the Senior Scientist for the CW-pulse measurements and D. L. Keir the Senior Scientist for the explosive measurements. Additional contributions were made to experiment planning by J. R. Lovett and J. D. Pugh. Preliminary analysis of acoustical data was done by H. P. Bucker and H. E. Morris. Assisting in the preliminary data reduction and analysis of the acoustic data was J. L. Thompson, an exchange scientist from RANRL, Sidney, Australia, and R. W. Townsen. Preliminary analysis of the environmental data was done by K. W. Nelson.

H. P. Bucker was the Scientist-in-Charge aboard the *DeSteiguer*, D. G. Good was Scientist-in-Charge aboard the *Lee*, and P. A. Hanson was Scientist-in-Charge aboard the *Cape*. Assisting with the acoustic measurements at sea were: T. E. Stixrud, C. R. Lisle, N. J. Martini, D. White, and R. F. Hosmer. The assistance of the officers and men of the *DeSteiguer*, *Lee*, and *Cape* in making the propagation loss measurements program successful is acknowledged.

ERRATA

TP 464, Vol. II

p. 46 At the bottom of the figure, the arrowhead on the left end of the horizontal line has been omitted. It should read:

|←——Most arrivals below noise to end of run

p. 58 The apparent data points at a range of 12 to 14 kyd and a propagation loss level of 123 dB are not real, but merely accidents of printing.

p. 67 The symbol for the noise level of 125 dB has been omitted. It was measured at a range of 36.0 kyd.

p. 72 The apparent data points at a range of 13 to 15 kyd and a propagation loss level of 131 dB are not real. These are also accidents of printing.

TP 465, Vol. II

p. 48 Figure C-6. The label at the top of the figure should read "distance from receivers, kyd" instead of "distance between measurements, kyd."

TP 465, Vol. III

pp. 29, 42, 59 Column heading "C" should be "$\bar{C}$."

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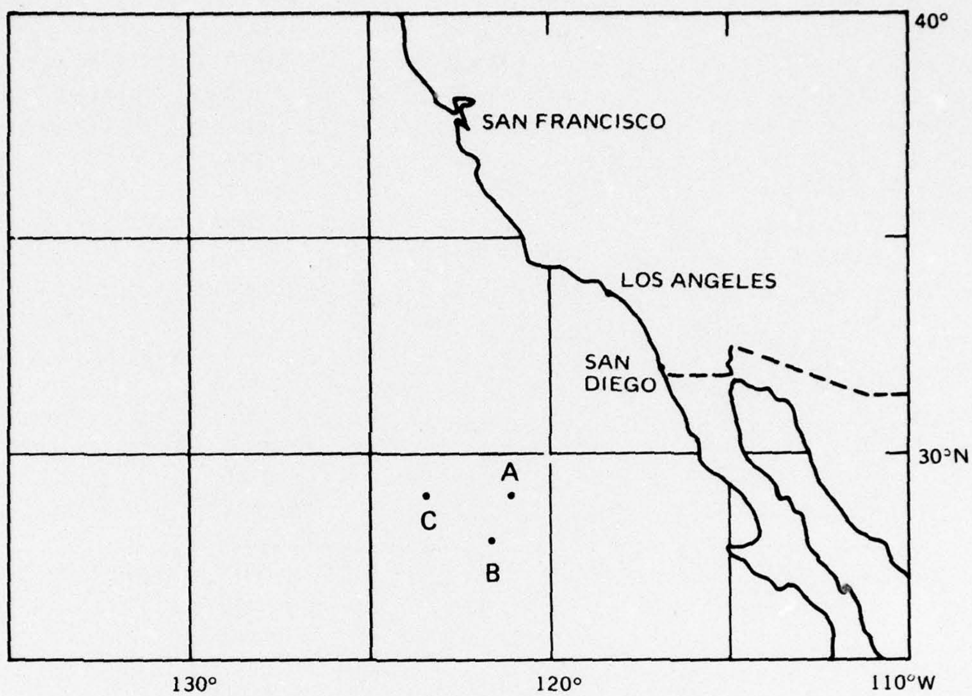

Figure 1. Location of experimental areas

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INTRODUCTION

This is the second in a series of five volumes describing the near-surface acoustic propagation loss measurements made during the SUDS I experiments. Volume I describes the instrumentation used to make the propagation loss measurements and the data reduction procedures. This volume (II) is a detailed report of the propagation loss measurements made during station 1, in which five acoustic experiments were completed. Figure 1 shows the track of the source ship during these experiments. Source ship speed was 3 knots for runs 1-4 and 6 knots for run 5. CW-pulsed sources were employed on runs 1-4 and explosive sources on run 5. Table 1 summarizes information pertinent to the individual propagation loss runs. Listed for each run are the beginning and ending dates and times, minimum and maximum range between the source and receiver ships, frequencies used, and source and receiver depths.

The detailed propagation loss measurements are contained in Appendices A-E. These appendices contain plots of propagation loss as a function of acoustic range for each frequency and receiver depth. CW pulsed sources were used on runs 1-4. The plots are the propagation loss for each received CW pulse as a function of acoustic range. At the bottom of each plot, remarks pertinent to that plot are indicated. The maximum acoustic range is indicated by the vertical arrow (↓) and individual noise level determinations by the symbol (∿). In addition, arrivals missing because of down periods when the recorder paper was being changed, periods when the source was inoperative, and periods when the arrivals, or most of the arrivals, were below noise are shown. Run 5 was an explosive source run. On these plots the noise-limited measurements are plotted as triangles. These measurements represent minimum possible propagation loss. Non-noise-limited measurements are plotted as squares.

Table 1. Summary of Propagation Loss Experiments, Station 1, 10-12 February 1972

Run	Date/time LST	Range, kyd Minimum	Range, kyd Maximum	Frequency, kHz	Source depth, m	Receiver depth, m
1	10/0251-0647	0.5	27.1	1.5	41	6/24/59/98/148
				2.5	41	
2	11/0052-0515	2.2	26.6	0.4	45	4/17/43/72/112
				1.0	42	
3	11/0721-1330	0.1	38.9	3.5	45	4/17/43/72/112
				5.0	42	
4	11/1438-2119	0.1	43.7	3.5	7	5/19/47/77/120
				5.0	4	
5	12/1125-1400	1.2	30.3	explosive	18	6/23/57/95/145/38

The remainder of this report discusses, for each propagation loss run, the average sound-speed profiles, average values for the AMOS parameters, and the major propagation loss features on the basis of visual comparisons of propagation loss plots.

The AMOS near-surface propagation loss prediction model requires single average values of isothermal layer depth, depressed channel depth, sea state, and sea surface temperature as inputs*. The isothermal layer depth is defined as the depth below the surface at which the temperature gradient from the surface is greater than –0.3°F/100 ft. Because of the effect of pressure, this results in a surface sound channel. The depressed channel is formed by an isothermal layer within the water column. This latter vertical temperature structure results in a sound-speed minimum near the top of the isothermal layer because of the effect of pressure on sound speed. The width of the depressed channel is approximately equal to the depth of the channel axis*. Figure 2 aids in defining these parameters.

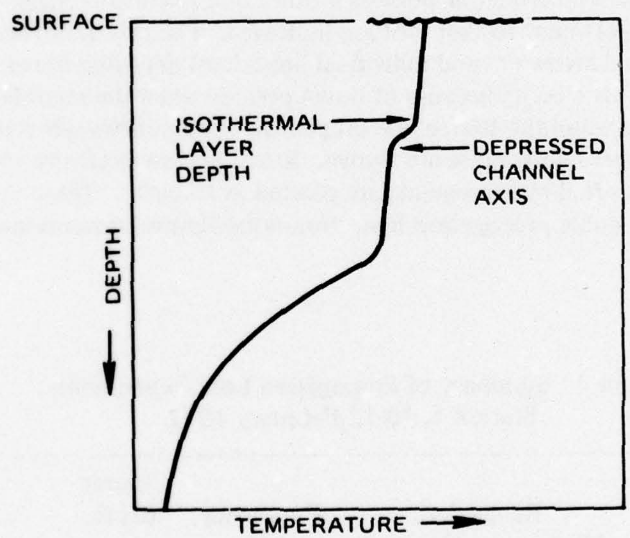


Figure 2. Vertical temperature profile.

Underwater Sound Laboratory Report 255A, Report on the Status of Project AMOS (Acoustic, Meteorological, and Oceanographic Survey), *by H. W. Marsh and M. Shulkin, March 1955 (revised May 1967).*

ENVIRONMENTAL SUMMARY AND COMMENTS

RUN 1 – 10 February 1972, 0251-0647 LST

During this run 1.5- and 2.5-kHz propagation losses were measured over acoustic ranges from 480 yd to 27.1 kyd. Figure 3 shows the track of the source and receiver ships and the 0251 and 0647 LST propagation paths. Figure 4 contains plots of source level and acoustic range, derived from nine travel-time measurements, versus time of day.

Average Sound-Speed Profile

Individual sound-speed profiles showed the presence of transient surface channels varying in depth from 6 to 50 m and small depressed channels at depths varying from 20 to 50 m. There were no persistent features of importance. The data were averaged to obtain a single average sound-speed profile applicable to the complete run. Figure 5 contains a plot of the average sound-speed profile. The average profile was characterized by a 20-m surface channel and a 70-m refractive channel, with the minimum sound speed at 200 m. The transient depressed channels, shown in individual profiles, were not retained in the average profile. The average thermistor chain data showed a depressed channel with axis at 50 m. During the experiment the source ship reported light airs to 3-knot winds, 1-ft waves, and 3-ft swell, while the receiver ship reported 4- to 5-knot winds, ripples, and 2-ft swell. No Waverider buoy measurements of sea-surface roughness were obtained during this experiment. Receiver 1 was located in the surface layer, receivers 2 and 3 below the layer, receiver 4 in the thermocline, and receiver 5 just above the refractive channel.

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements, and applicable to the run 1 experiment are:

number of observations	1431
isothermal layer depth	128 ft
depressed channel axis	148 ft
surface water temperature	58.6°F
sea state	1

Discussion

The propagation loss measurements are plotted in Appendix A. A visual comparison of these plots suggests the following:

- A consistent minimum of low propagation loss was observed over the range interval from 22.8 kyd to 23.6 kyd for both frequencies and all receiver depths except for the 98-m

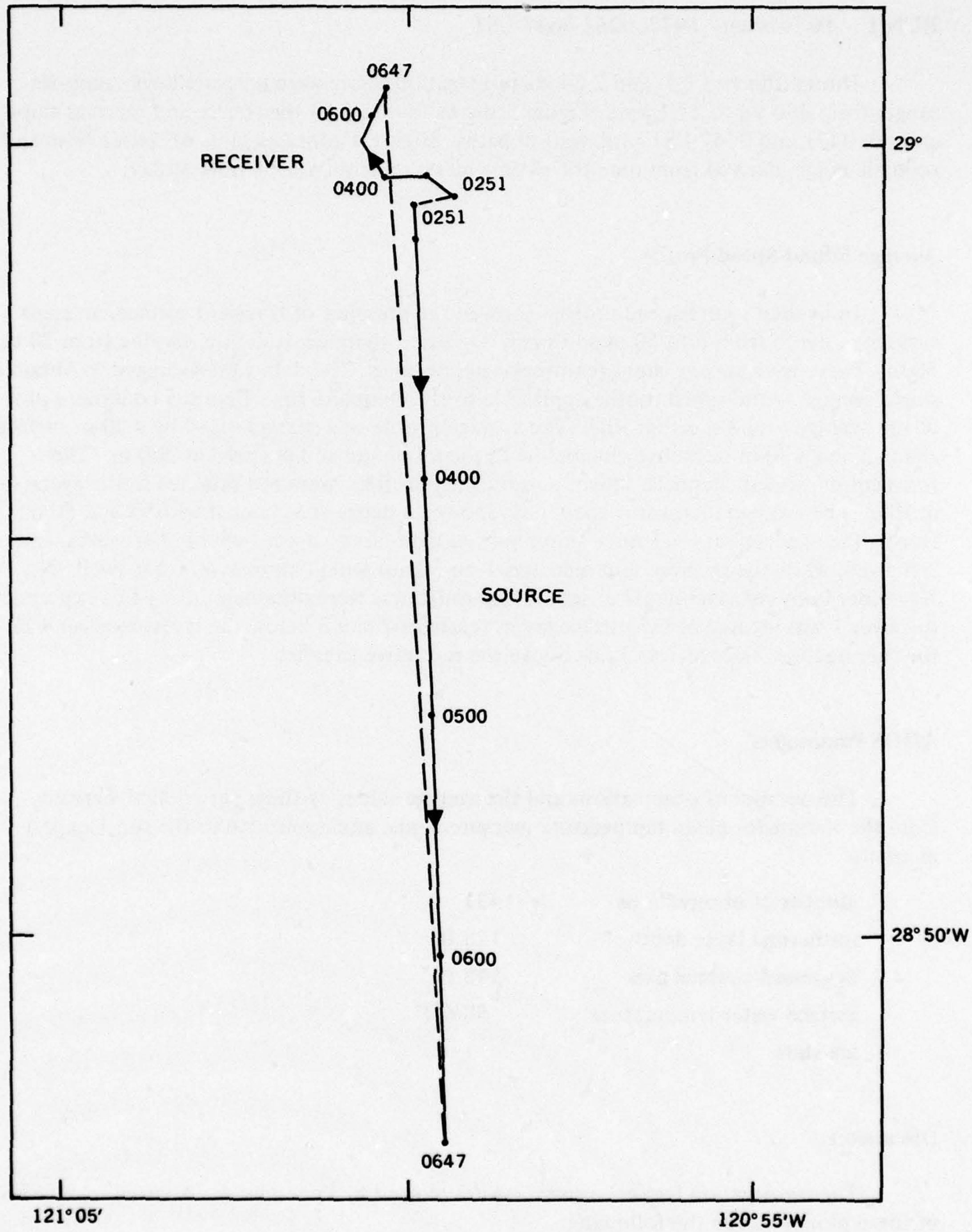
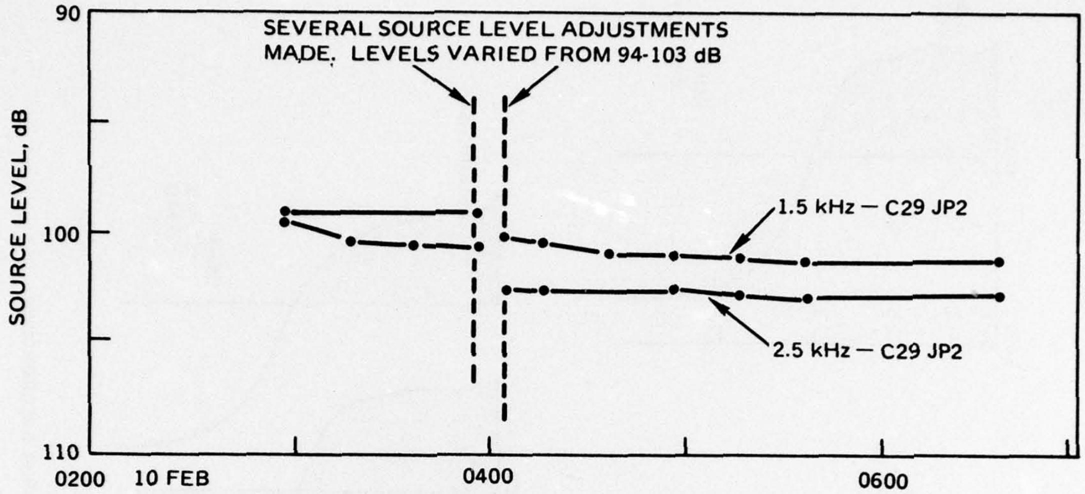


Figure 3. Station 1, run 1. Tracks of source and receiver ships and 0251 LST and 0647 LST propagation paths.



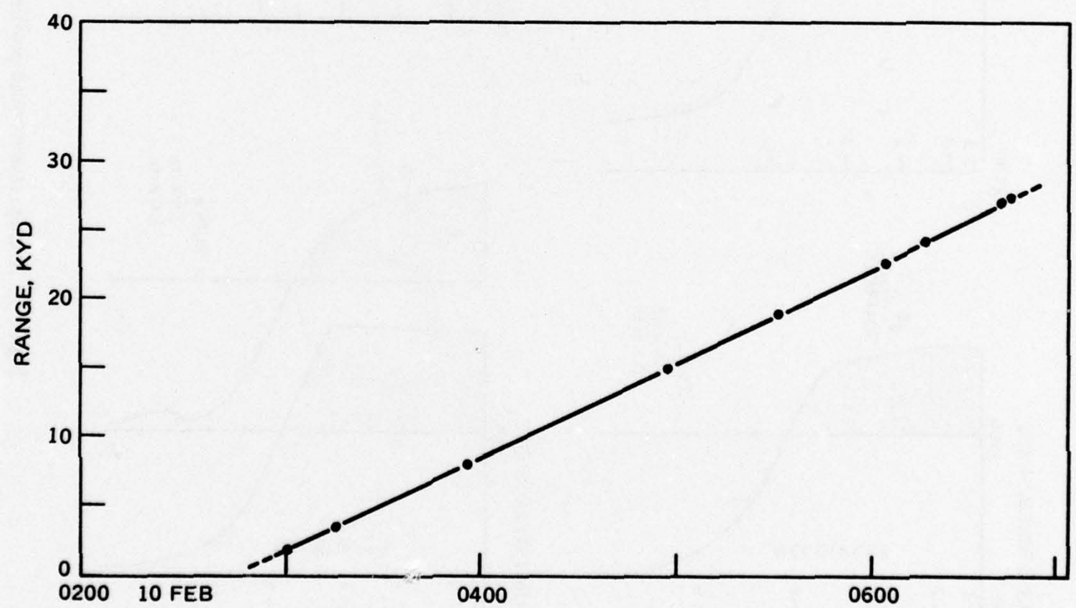


Figure 4. Station 1, run 1. Source level and acoustic range versus time of day (LST).

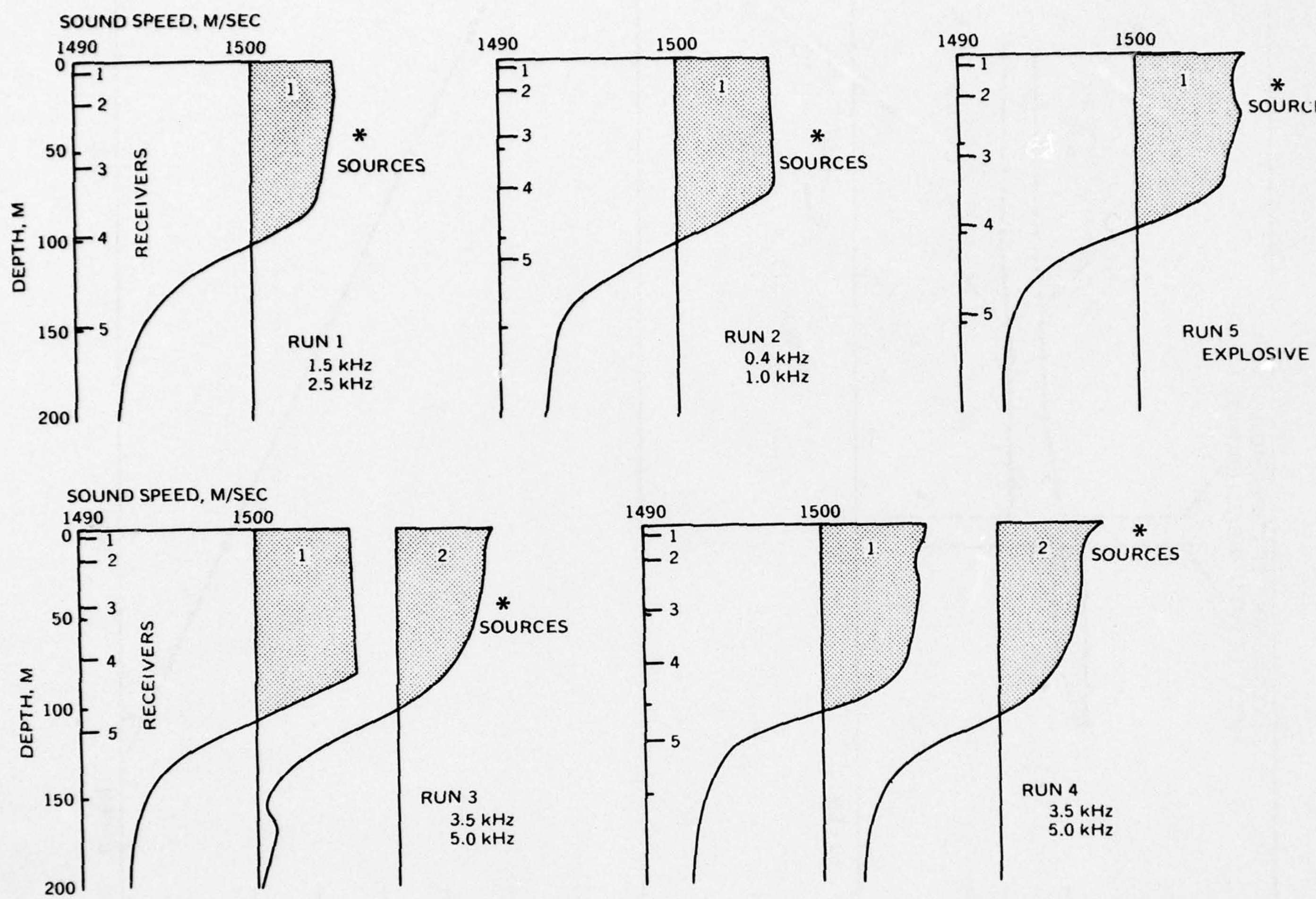


Figure 5. Average sound-speed profile summary for station 1 acoustic runs.

receiver at 1.5 kHz, where it may be masked by a noise level about 10 dB higher than the other receivers noise levels. Table 2 lists the ranges and propagation losses (PL) for each frequency and receiver depth. Note the lack of depth dependence for the three deepest receivers. The propagation loss for these receivers is greater than that observed on the shallowest receiver.

- Figures 6 and 7 show the variation of propagation loss with range for the shallowest (6-m) and the deepest (148-m) receivers for each frequency*. There was no difference between receivers out to 13.0 kyd at 1.5 kHz and 15.0 kyd at 2.5 kHz. At greater ranges, the 148-m receiver recorded a propagation loss about 15 dB greater than the 6-m receiver. The minimum propagation loss at a nominal 23.0 kyd is quite evident.

- Out to ranges of about 19.0 kyd (1.5 kHz) and about 25.0 kyd (2.5 kHz) there was little difference in propagation loss versus range for the three deepest receivers. At 1.5 kHz there also was no difference between the shallowest receivers.

- Out to 5.0 kyd no depth dependence was observed at either frequency.

- The propagation loss at 2.5 kHz was a nominal 10 dB greater than the 1.5-kHz propagation loss. Figure 8 illustrates this difference.

- Arrivals were received from the maximum range of the run (27.1 kyd) on the three shallowest receivers at 2.5 kHz and from 26.8 kyd and 27.0 kyd on the 98-m and 148-m receivers, respectively. At 1.5 kHz, arrivals were received from the maximum range on the 24- and 59-m receivers and from 26.9, 24.0, and 24.9 kyd on the 6-, 98-, and 148-m receivers, respectively.

RUN 2 – 11 February 1972, 0052-0515 LST

During this run 0.4- and 1.0-kHz propagation losses were measured over acoustic ranges from 2.2 to 26.6 kyd. Figure 9 shows the track of the source and receiver ships and the 0052 and 0515 LST propagation paths. The plane of the propagation paths is a changing

Table 2. Range (kyd) and Propagation Loss (dB) of Propagation Loss Minimum

Receiver Depth, m	1.5 kHz		2.5 kHz	
	Range	PL	Range	PL
6	22.9	67	23.5	78
24	22.9	70	23.4	86
59	23.3	82	23.6	96
98	–	–	23.0	97
148	22.8	82	23.2	95

**A maximum of four CW pulses were transmitted each minute. For simplification, all pulses received during each minute (i.e., 1, 2, 3, or 4) were averaged. These average values are plotted on all propagation loss plots used in the text of this report.*

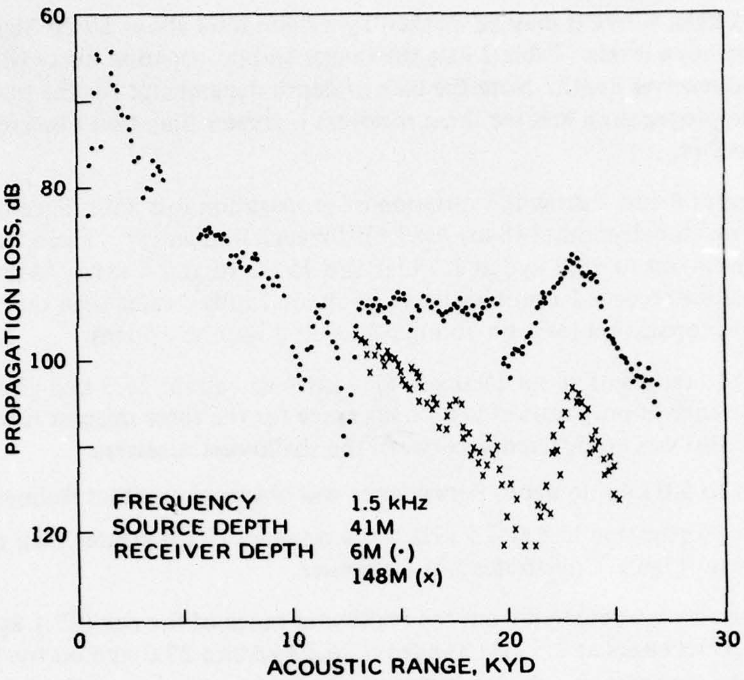


Figure 6. Station 1, run 1. Acoustic range and depth dependence.

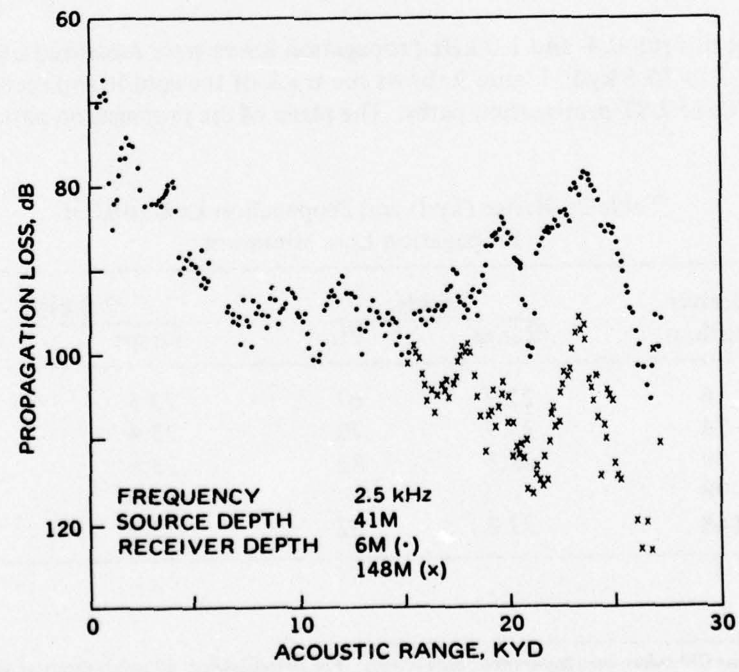


Figure 7. Station 1, run 1. Acoustic range and depth dependence.

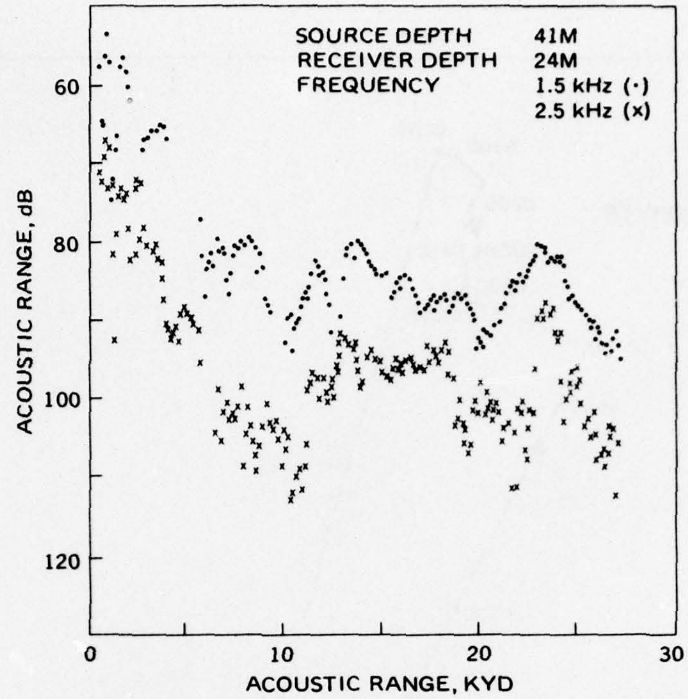


Figure 8. Station 1, run 1. Acoustic range and frequency dependence.

function of time and at no time coincides with the plane of the source ship measurements. Hence, the environmental measurements made by the source ship are not necessarily descriptive of environmental conditions in the propagation path planes. Figure 10 contains plots of source level and acoustic range, derived from eight travel time measurements, versus time-of-day.

Average Sound-Speed Profile

Individual sound-speed profiles showed the presence of transient surface channels varying in depth from 10 to 80 m and small depressed channels at depths varying from 20 to 50 m. There were no persistent features of importance. The data were averaged to obtain a single average sound-speed profile applicable to the complete run. Figure 5 contains a plot of the average profile. The average profile is characterized by a 68-m surface channel and an isospeed layer from 200 to 300 m. The transient depressed channels shown in the individual profiles are not retained in the average profile. During the experiment the source ship reported 10-knot winds, 2-ft waves, and 5 ft swell, while the receiver ship reported 12-knot winds, 1-ft waves, and 3- to 4-ft swell. Also, sea-surface roughness measurements were obtained by the Waverider buoy for the complete run. Spectral analysis of these measurements reveals the presence of two trains of swell centered at about 11.0- and 15.7-sec wave periods. Also present are 1.5- to 2.5-sec wind waves. Most of the sea-surface roughness is associated with the 11.0- and 15.7-sec swell trains. Receivers 1, 2, and 3 are in the surface sound channel, receiver 4 is just below the surface sound channel, and receiver 5 is in the thermocline.

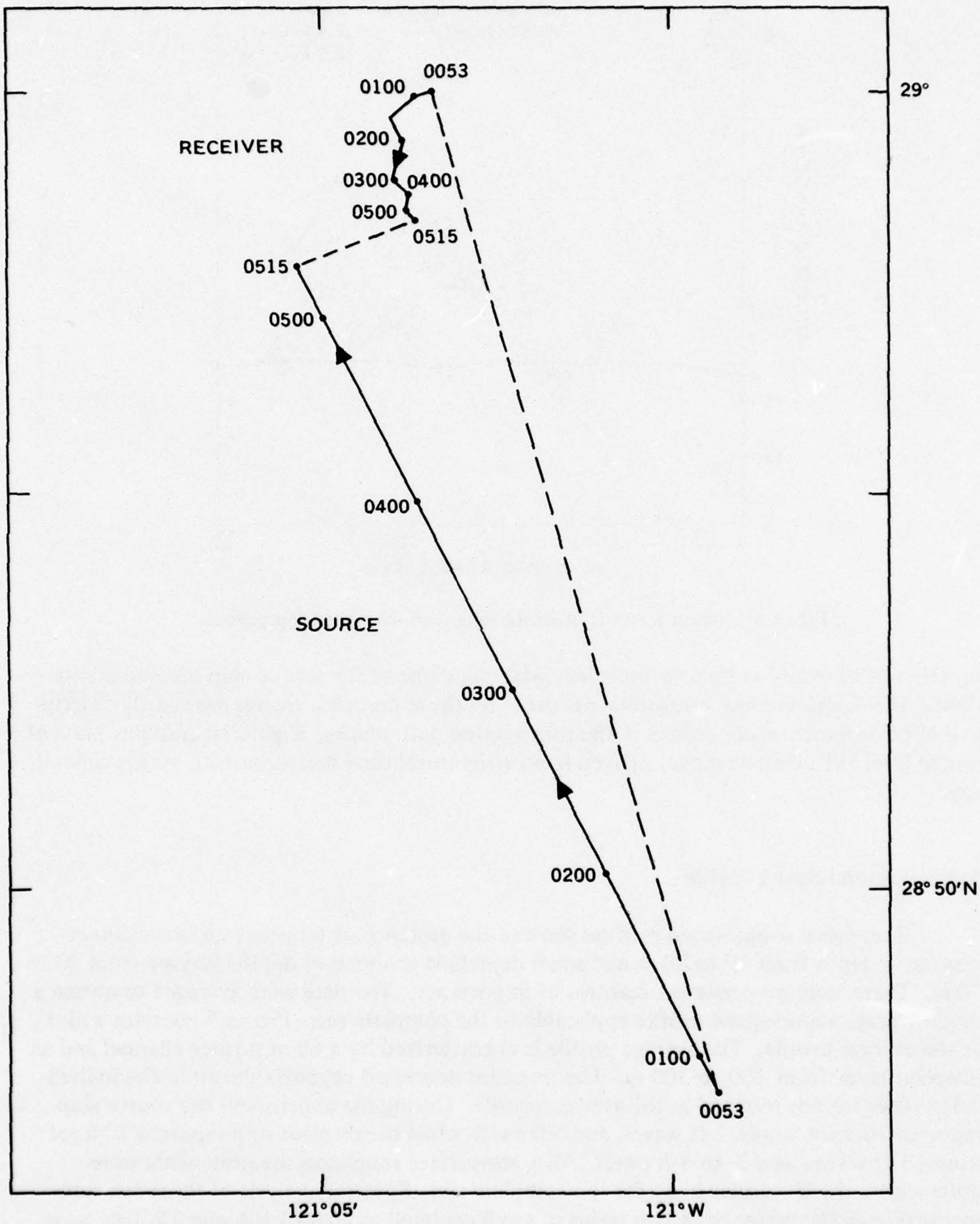
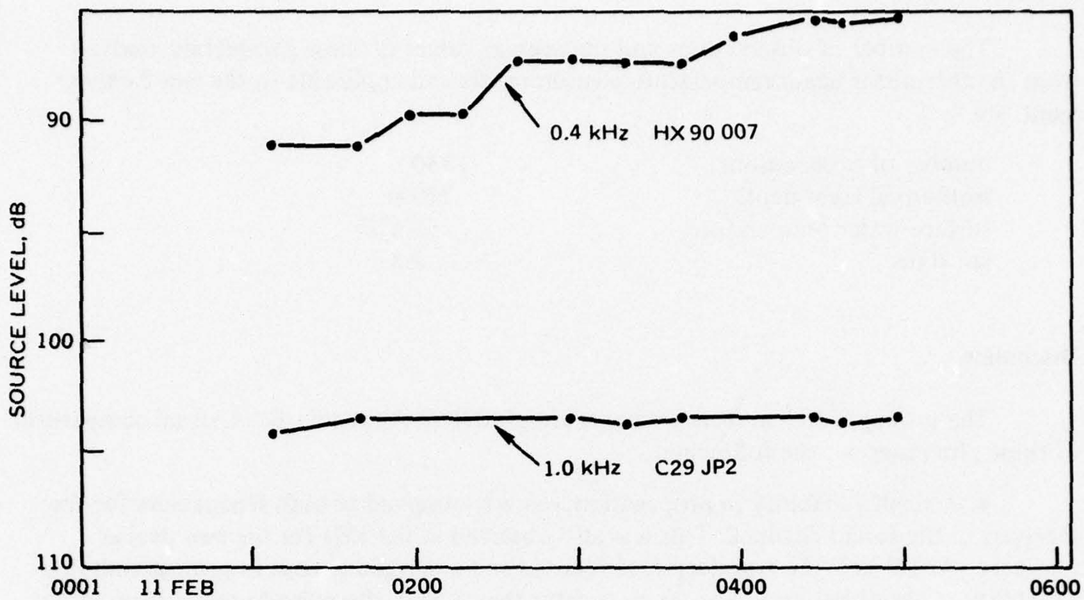


Figure 9. Station 1, run 2. Tracks of source and receiver ships and 0053 LST and 0515 LST propagation paths.



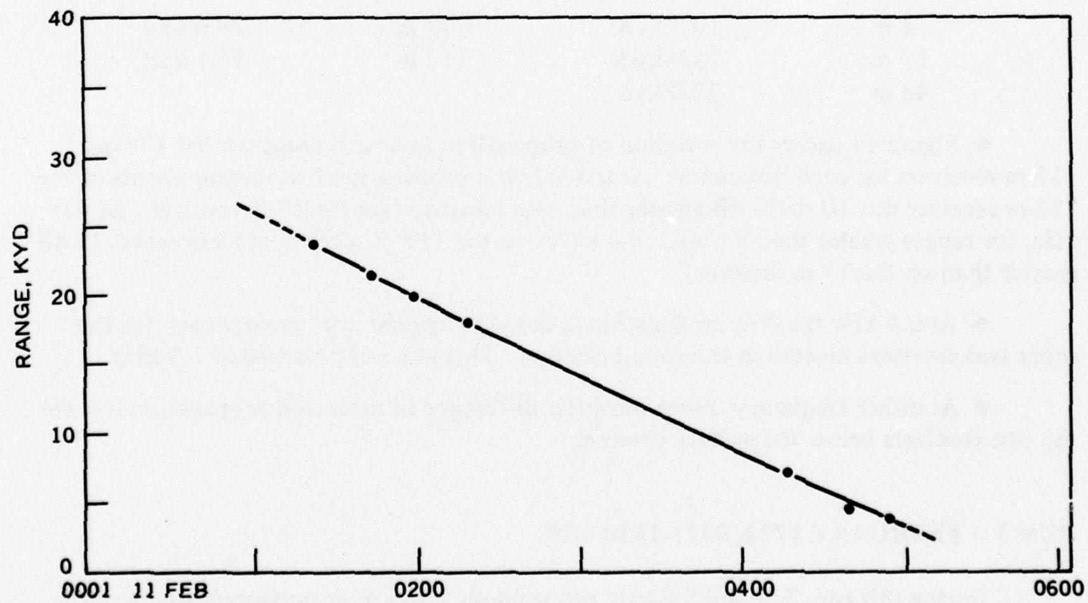


Figure 10. Station 1, run 2. Source level and acoustic range versus time of day (LST).

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements and applicable to the run 2 experiment, are:

number of observations	1350
isothermal layer depth	240 ft
surface water temperature	58.8°F
sea state	2-3

Discussion

The propagation loss measurements are plotted in Appendix B. A visual comparison of these plots suggests the following:

- A small variability in propagation loss was observed at both frequencies for the receivers in the sound channel. This was also observed at 0.4 kHz for the two deeper receivers. At 1.0 kHz the two deep receivers showed a marked change in propagation loss variability at about 8.0 kyd. For ranges greater than 8 kyd, the pulse-to-pulse propagation loss exhibits a random variability of about ±5 dB.

- A limited maximum range of arrivals was observed at 0.4 kHz. The maximum possible range was 26.6 kyd. For each receiver all, or nearly all, of the arrivals were below noise for ranges greater than the following:

4 m	19.7 kyd	72 m	19.0 kyd
17 m	23.8 kyd	112 m	17.1 kyd
43 m	22.0 kyd		

- Figure 11 shows the variation of propagation loss with range for the 17- and 112-m receivers for each frequency. At 0.4 kHz the propagation loss measurements at the 112-m receiver was 10 to 20 dB greater than that measured on the 17-m receiver. At 1.0 kHz, for ranges greater than 9.0 kyd, the losses on the 112-m receiver are a nominal 25 dB greater than on the 17-m receiver.

- At 0.4 kHz the 4-m propagation losses were consistently greater than for the other two receivers located in the sound channel. This was not observed at 1.0 kHz.

- At either frequency, there was little difference in measured propagation loss for the two receivers below the surface channel.

RUN 3 – FEBRUARY 1972, 0721-1330 LST

During this run, 3.5- and 5.0-kHz propagation losses were measured over acoustic ranges from 53 yd to 38.9 kyd. Figure 12 shows the track of the source and receiver ships, the 1330 LST propagation path, and the location of a sound-speed profile boundary which was crossed at about 1130 LST at an acoustic range from the receivers of 27.5 kyd. Figure 13 contains plots of source level and acoustic range, derived from 12 travel-time measurements,

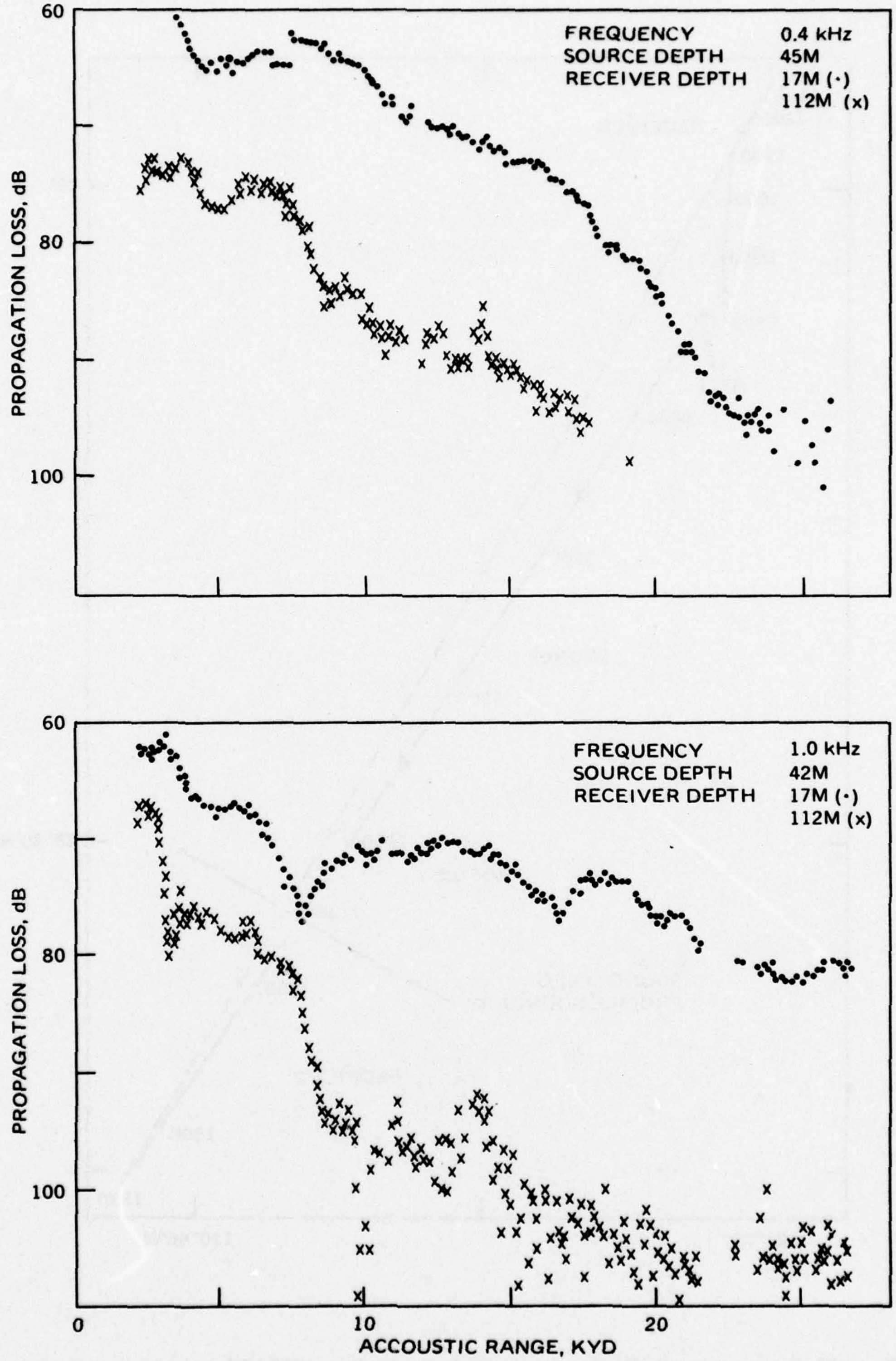


Figure 11. Station 1, run 2. Acoustic range and depth dependence.

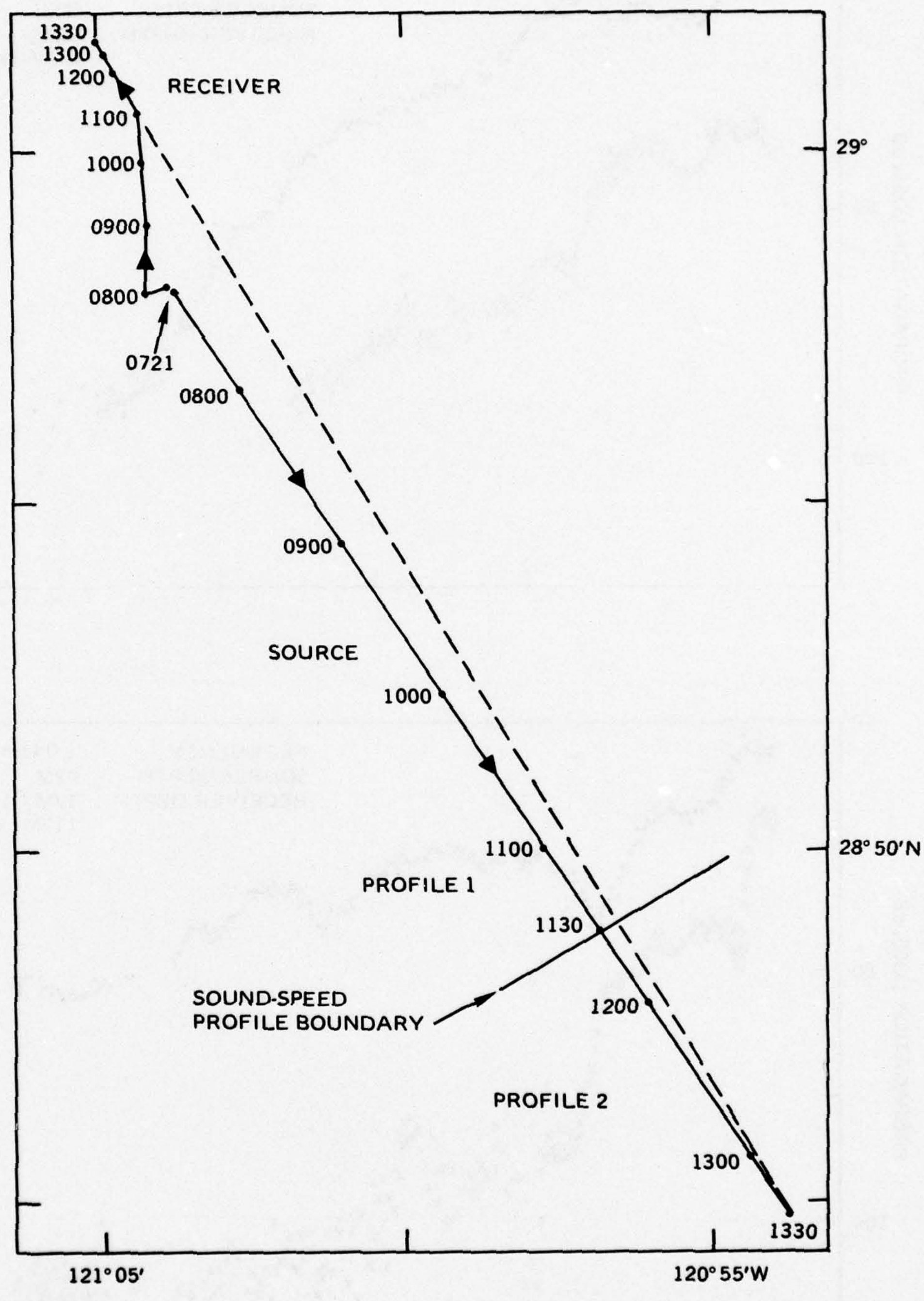
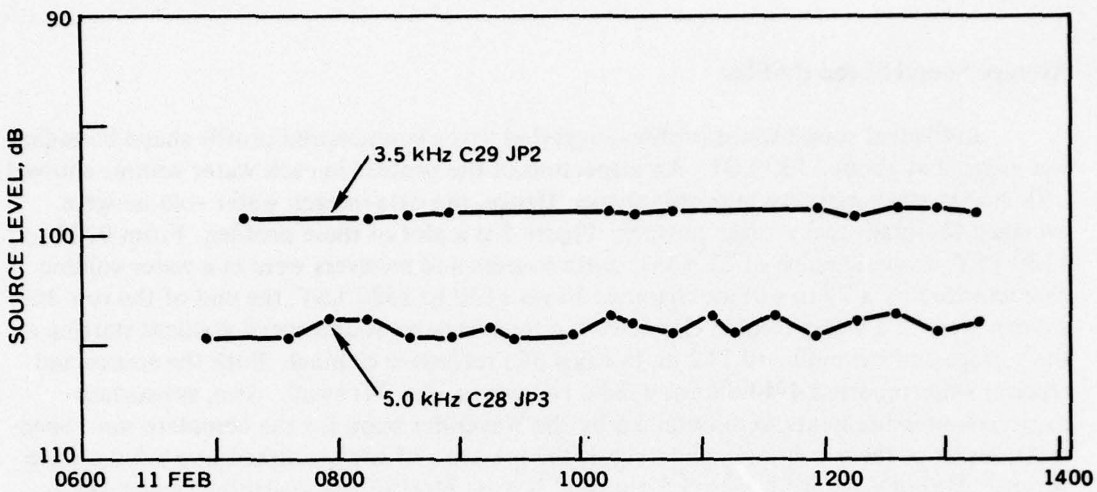


Figure 12. Station 1, run 3. Tracks of source and receiver ships, 1330 LST propagation path, and location of sound-speed profile boundary.



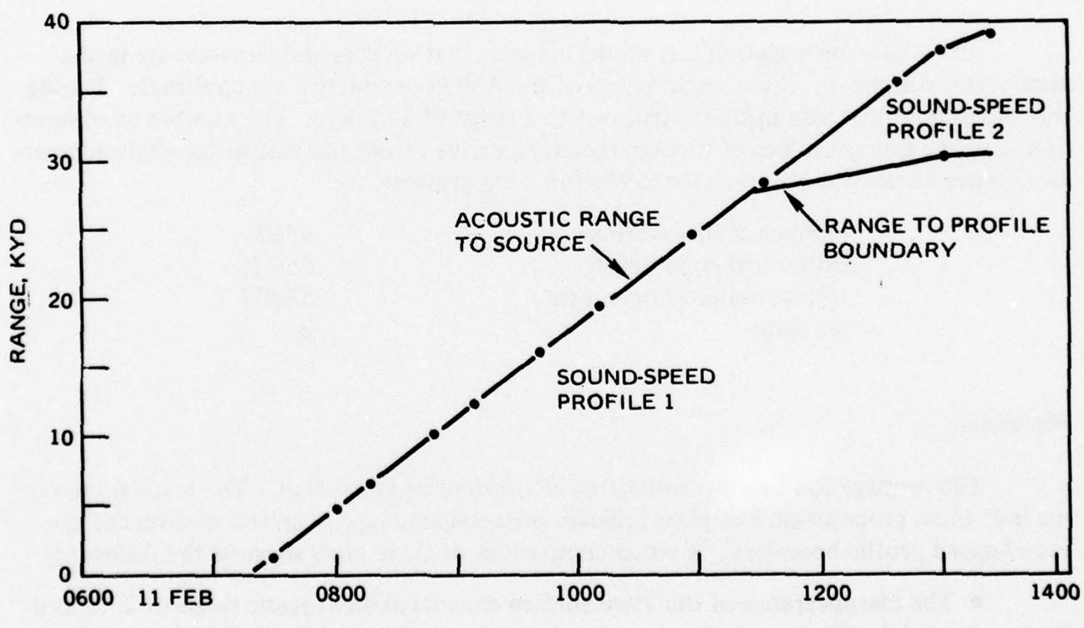


Figure 13. Station 1, run 3. Source level and range from receiver versus time of day (LST).

versus time of day. Also shown is the range of the sound-speed profile boundary as a function of time.

Average Sound-Speed Profiles

Individual sound-speed profiles suggested that a sound-speed profile shape boundary was crossed at about 1130 LST. An inspection of the profiles in each water volume showed little horizontal variability in profile shape. Hence, the data in each water volume were averaged to obtain two average profiles. Figure 5 is a plot of these profiles. From 0721 to 1130 LST, acoustic range of 27.4 kyd, both sources and receivers were in a water volume characterized by a 79-m surface channel. From 1130 to 1330 LST, the end of the run, the sources were in a water volume characterized by a negative sound-speed gradient starting at the surface and extending to 152 m, the axis of a refractive channel. Both the source and receiver ships reported 4- to 8-knot winds, 1-ft waves, and 3-ft swell. Also, sea-surface roughness measurements were obtained by the Waverider buoy for the complete run. Spectral analysis of these measurements reveals the presence of swell centered at a 9.5-sec wave period. Also present are 1.5- to 3.5-sec wind waves. Most of the sea-surface roughness is associated with the 9.5-sec swell. Receivers 1, 2, 3, and 4 were in the surface sound channel, and receiver 5 was in the thermocline.

AMOS Parameters

The AMOS propagation loss model assumes that sources and receivers are in the same water volume, in which single values of the AMOS parameters are applicable. During this experiment this assumption is true out to a range of 27.5 kyd. The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements and applicable to the run 3 experiment, are:

number of observations	1503
isothermal layer depth	259 ft
surface water temperature	58.8°F
sea state	2

Discussion

The propagation loss measurements are plotted in Appendix C. The vertical lines on the individual propagation loss plots indicate the acoustic range from the receivers of the sound-speed profile boundary. A visual comparison of these plots suggests the following:

- The disappearance of the 79-m surface channel at an acoustic range of 27.5 kyd has no observable effect on the propagation loss measured by the three shallowest receivers.

- For the three shallowest receivers, arrivals were recorded at both frequencies out to the maximum range of the experiment. For the 72-m receiver, most of the arrivals were below noise for ranges greater than 34.8 and 35.7 kyd at 3.5 and 5.0 kHz, respectively. For the 112-m receiver, most of the arrivals at 3.5 kHz were below noise for ranges between 18.6 and 25.3 kyd and for those greater than 34.6 kyd, with the last arrival being recorded

at a range of 38.0 kyd. For the same receiver, all 5.0-kHz arrivals between 32.0 and 34.5 kyd were below noise, with the last arrival being received for a range of 37.0 kyd. Also most arrivals were below noise between 20.8 and 25.6 kyd.

- At both frequencies there was little difference in propagation loss for the three shallowest receivers. This was also true for the two deepest receivers. For the two deep receivers, the 3.5-kHz propagation loss for ranges greater than about 12 kyd was 10 to 20 dB greater than for the three shallow receivers. At 5.0 kHz, this was also true for ranges greater than about 6.0 kyd. This is illustrated by Fig. 14.

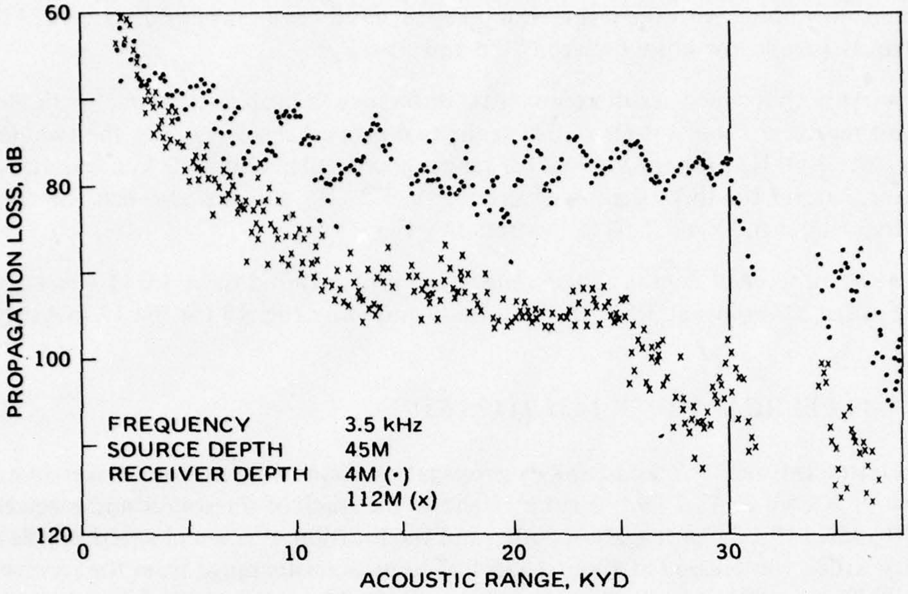
- At all receiver depths and all ranges, the propagation loss at 5.0 kHz was greater than the propagation loss at 3.5 kHz. This is illustrated by Fig. 15 for the 17-m receiver.

RUN 4 – 11 FEBRUARY 1972, 1438-2119 LST

During this run, 3.5- and 5.0-kHz propagation losses were measured over acoustic ranges from 100 yd to 43.7 kyd. Figure 16 shows the track of the source and receiver ships, the 1438 and 2119 LST propagation paths, and the location of a sound-speed profile shape boundary which was crossed at about 1635 LST at an acoustic range from the receivers of 30.0 kyd. This was the same boundary that was crossed on run 3 about 5 hours earlier. During this run the source ship did not maintain a constant course heading, but made several small course changes, with a major change of 55° being executed at 1910 LST. This resulted in the source ship crisscrossing the acoustic propagation paths. Figure 17 contains plots of source level and acoustic range, derived from 13 travel-time measurements, versus time of day. Also shown in Fig. 17 is the range of the sound-speed profile boundary as a function of time.

Average Sound-Speed Profiles

Individual sound-speed profiles suggested that a sound-speed profile shape boundary was crossed at about 1635 LST. The individual profiles in both water volumes showed transient surface, depressed, and refractive channels. Along the source ship track, the thermistor chain measurements showed considerable variability in temperature from 61 to 147 m. Above and below those depths, the variability was small. The measurements made in each water volume were averaged to obtain two sound-speed profiles. Figure 5 contains a plot of these profiles. At the beginning of the run, the sources were in a water volume characterized by a negative sound-speed gradient starting at the surface, and the receivers were in a water volume characterized by a 12-m depressed channel with minimum sound speed at 20 m and a 70-m refractive channel with minimum sound speed at 200 m. At an acoustic range of 30.0 kyd the sources were towed into the same water volume as the receivers. The 79-m surface channel present in the profile 1 volume during run 3 was eliminated by daytime heating of the upper layers of the ocean and was replaced by the depressed channel. The source ship reported 8-knot winds, increasing to 15 knots during the run, 2-ft waves, and 4-ft swell, while the receiver ship reported 10- to 12-knot winds, 1-ft waves, and 3- to 5-ft swell. Sea-surface roughness measurements were obtained by the Waverider buoy for the complete run. Spectral analysis of these measurements indicated a change of spectra with time. At the beginning of the run, 1.7-sec wind waves were present, with the period



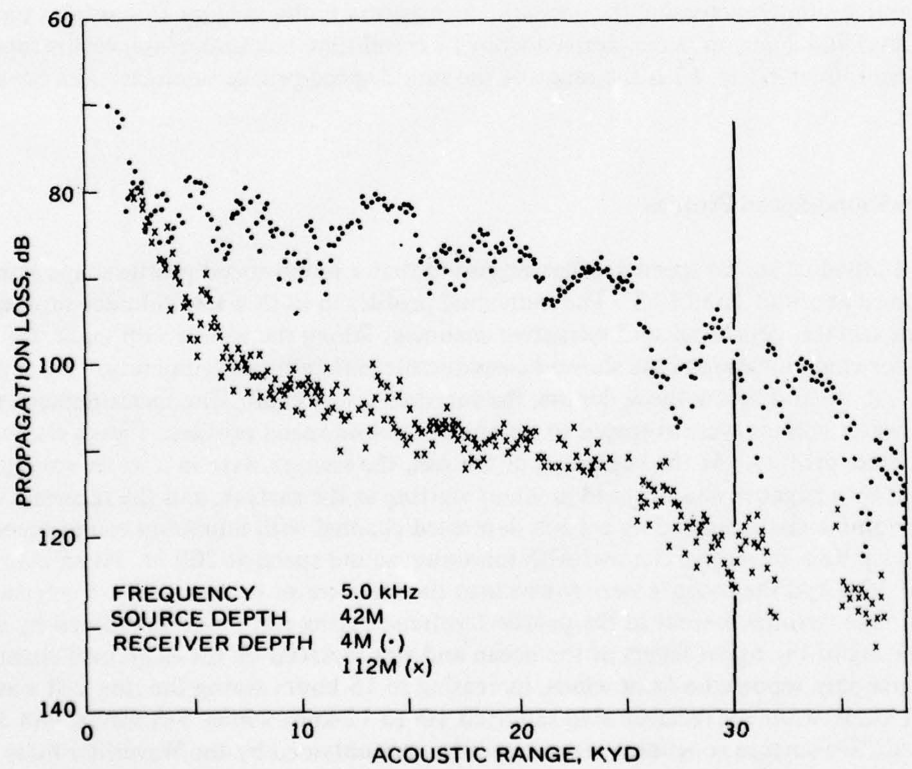


Figure 14. Station 1, run 3. Acoustic range and depth dependence.

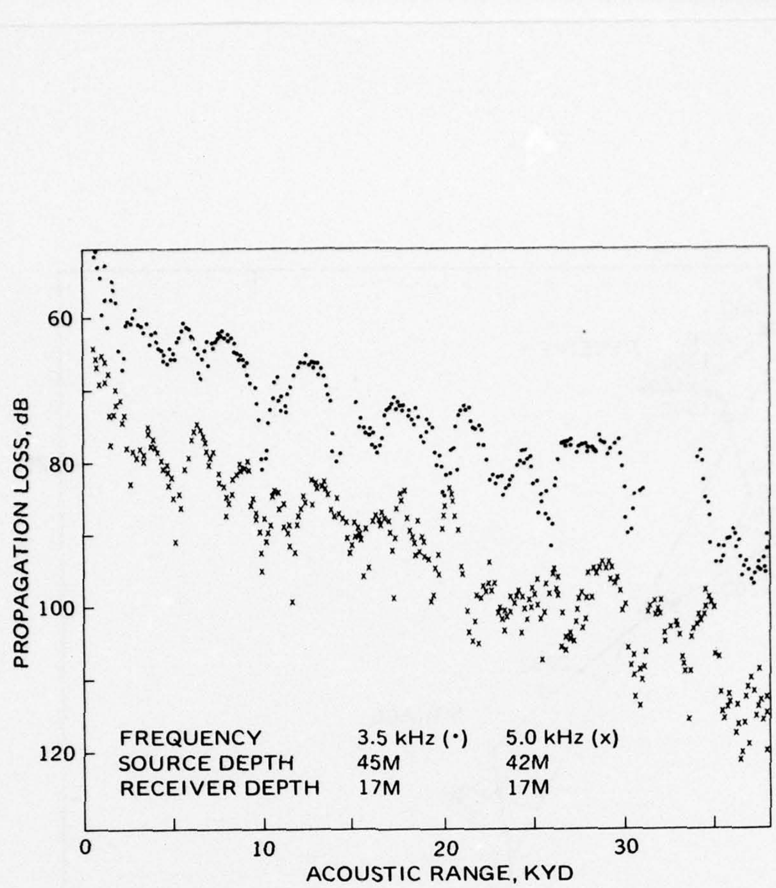


Figure 15. Station 1, run 3. Acoustic range and frequency dependence.

increasing to 3.2 sec as the run progressed. This change was associated with the increasing speed of the local winds as reported by the source ship. During the beginning of the run, a 9.7-sec swell was present. This swell tended to decay during the run, although it was still detectable at the end of the run. During the last 2 to 3 hours of the run, a 14.4-sec swell moved into the area. Most of the sea-surface roughness was associated with the swell. Receivers 1, 3, and 4 were in the surface layer, receiver 2 was at the axis of the depressed channel, and receiver 5 was in the thermocline about 45 m above the refractive channel.

AMOS Parameters

The AMOS propagation loss model assumes that sources and receivers are in the same water volume, in which single values of the AMOS parameters are applicable. For this experiment this assumption is true out to a range of 30.0 kyd. The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements, and applicable to the run 4 experiment are:

number of observations	1575
isothermal layer depth	0 ft
surface water temperature	59.4°F
sea state	3

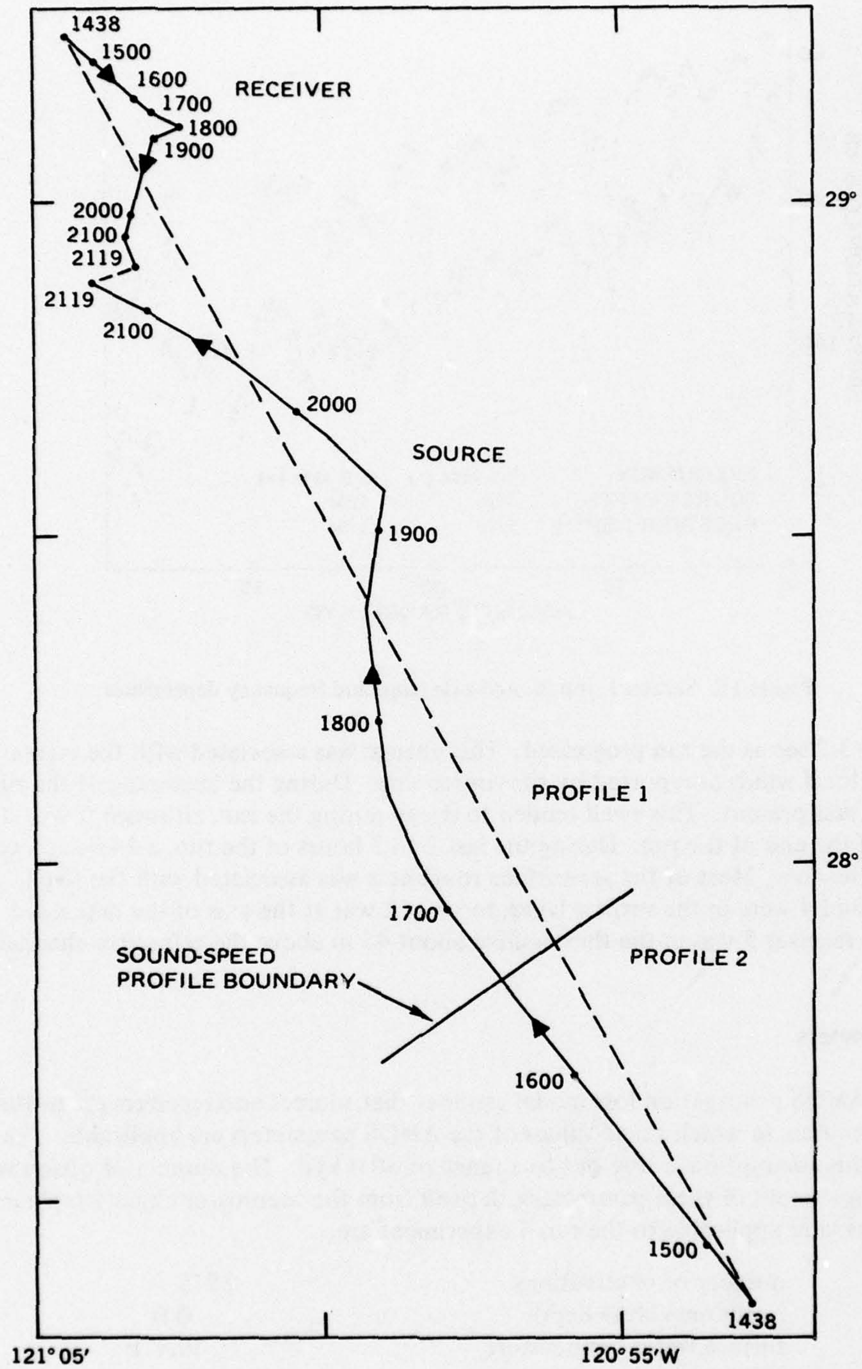
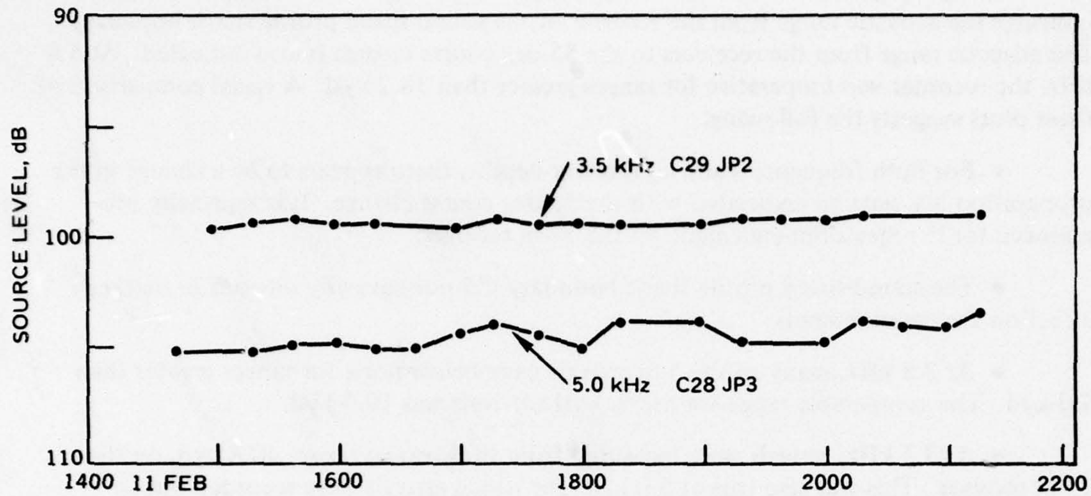


Figure 16. Station 1, run 4. Tracks of source and receiver ships, 1438 LST and 2119 LST propagation paths, and location of sound-speed profile boundary.



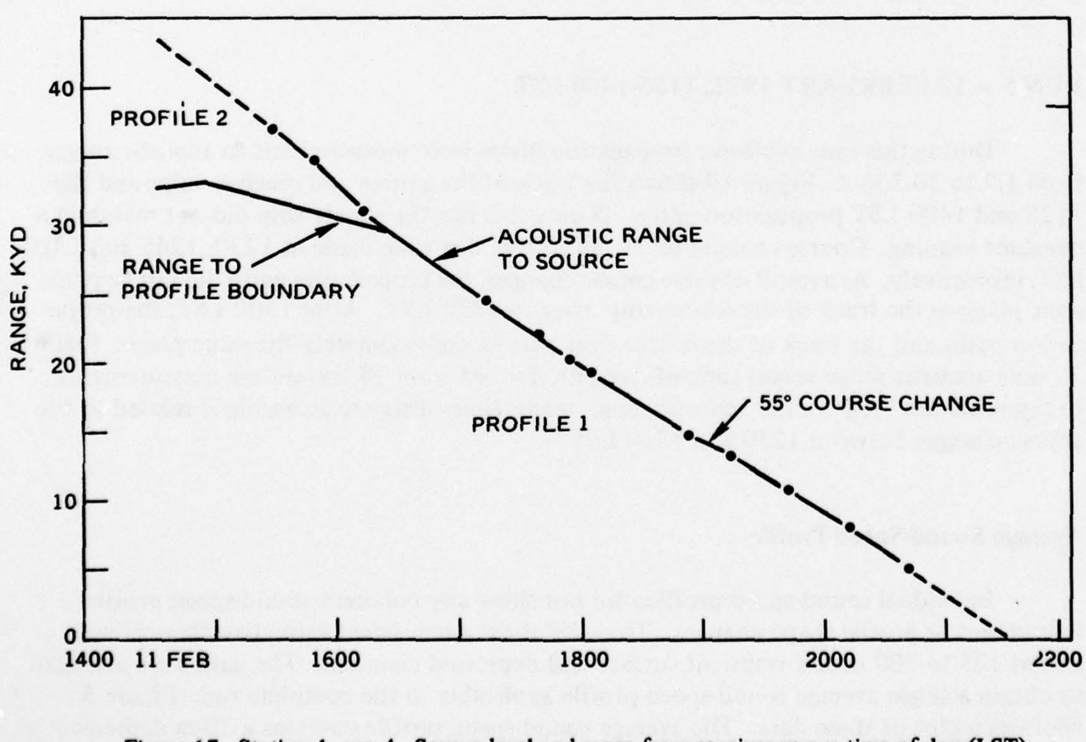


Figure 17. Station 1, run 4. Source level and range from receiver versus time of day (LST).

Discussion

The propagation loss measurements are plotted in Appendix D. The vertical line indicates the acoustic range from the receiver of the sound-speed profile shape boundary. The acoustic range from the receivers to the 55-deg course change is also indicated. At 5.0 kHz, the recorder was inoperative for ranges greater than 38.2 kyd. A visual comparison of these plots suggests the following:

- For both frequencies and all receiver depths, there appears to be a change in the propagation loss pattern associated with the 55-deg course change. It is especially pronounced for the measurements made on the 77-m receiver.

- The sound-speed profile shape boundary did not have any obvious or marked effect on the measurements.

- At 3.5 kHz, many of the 5-m arrivals were below noise for ranges greater than 7.0 kyd. The comparable range for the 5.0-kHz arrivals was 10.9 kyd.

- At 3.5 kHz, arrivals were measured from the greatest range, 40.8 kyd, on the 19-m receiver. This was also true at 5.0 kHz, for which arrivals were recorded out to 38.2 kyd. At that range the 5-kHz recorder became inoperative.

- At all receiver depths and ranges, the propagation loss at 5.0 kHz was greater than that measured at 3.5 kHz. This is illustrated by Fig. 18.

- Some of the propagation loss plots exhibited modal patterns. These patterns were masked, in many cases, by large pulse-to-pulse variability.

RUN 5 – 12 FEBRUARY 1972, 1125-1400 LST

During this run, explosive propagation losses were measured out to acoustic ranges from 1.2 to 30.3 kyd. Figure 19 shows the track of the source and receiver ships and the 1125 and 1400 LST propagation paths. During this run the source ship did not maintain a constant heading. Course changes of 71, 37 and 41 deg were made at 1230, 1245 and 1310 LST, respectively. As a result of these course changes, the propagation paths did not lie in the same plane as the track of the source ship prior to 1330 LST. After 1300 LST, the propagation paths and the track of the source ship were in approximately the same plane. Figure 20 is an acoustic range versus time-of-day plot derived from 28 travel-time measurements. In figure 20 the "jog" in the acoustic range versus time-of-day relationship is related to the course changes between 1230 and 1310 LST.

Average Sound-Speed Profile

Individual sound-speed profiles did not show any coherent sound-speed profile boundaries or profile shape changes. They did show a consistent refractive channel with axis at 125 to 200 m and transient surface and depressed channels. The data were averaged to obtain a single average sound-speed profile applicable to the complete run. Figure 5 contains a plot of these data. The average sound-speed profile contains a 20-m depressed

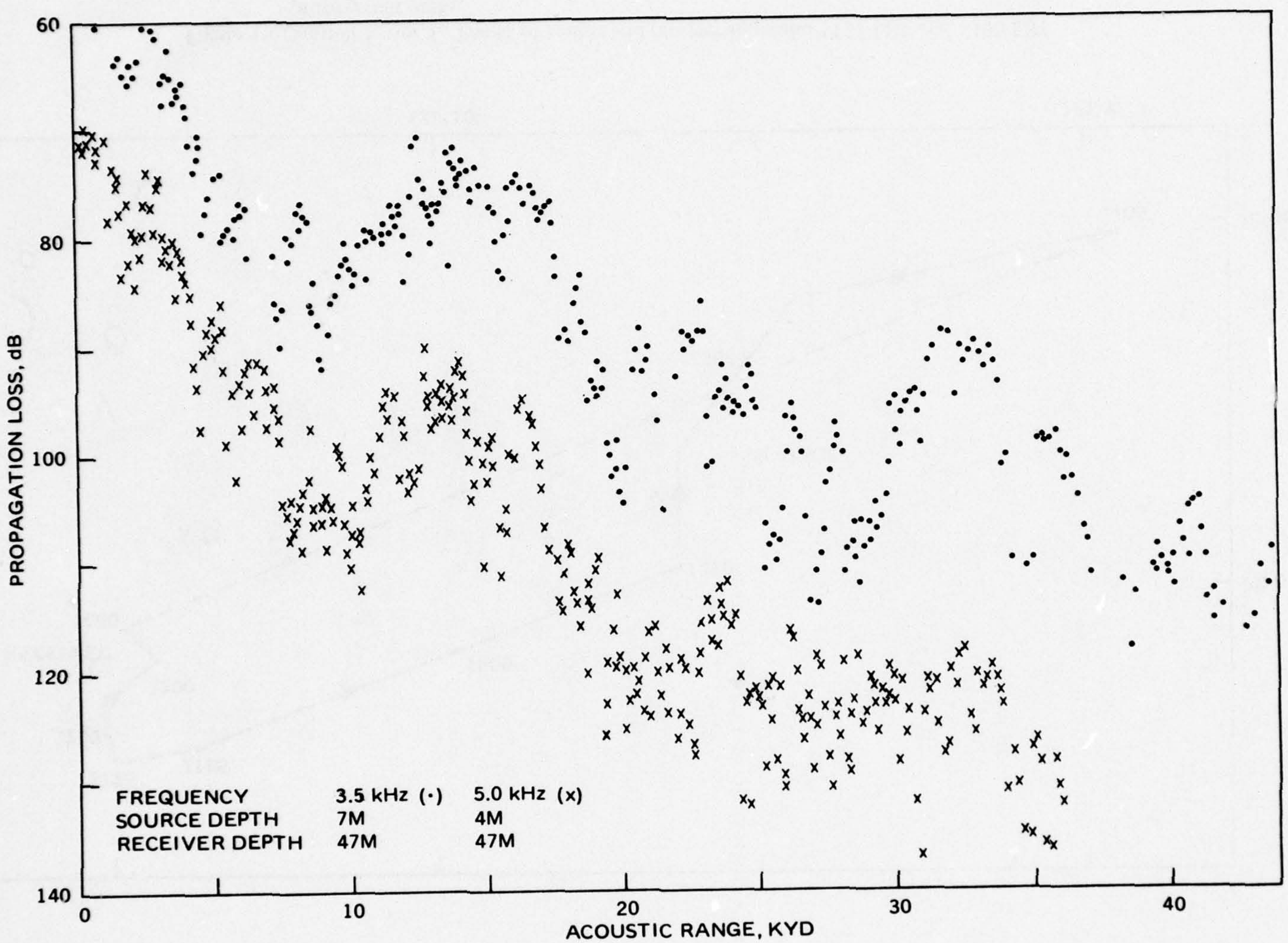


Figure 18. Station 1, run 4. Acoustic range and frequency dependence.

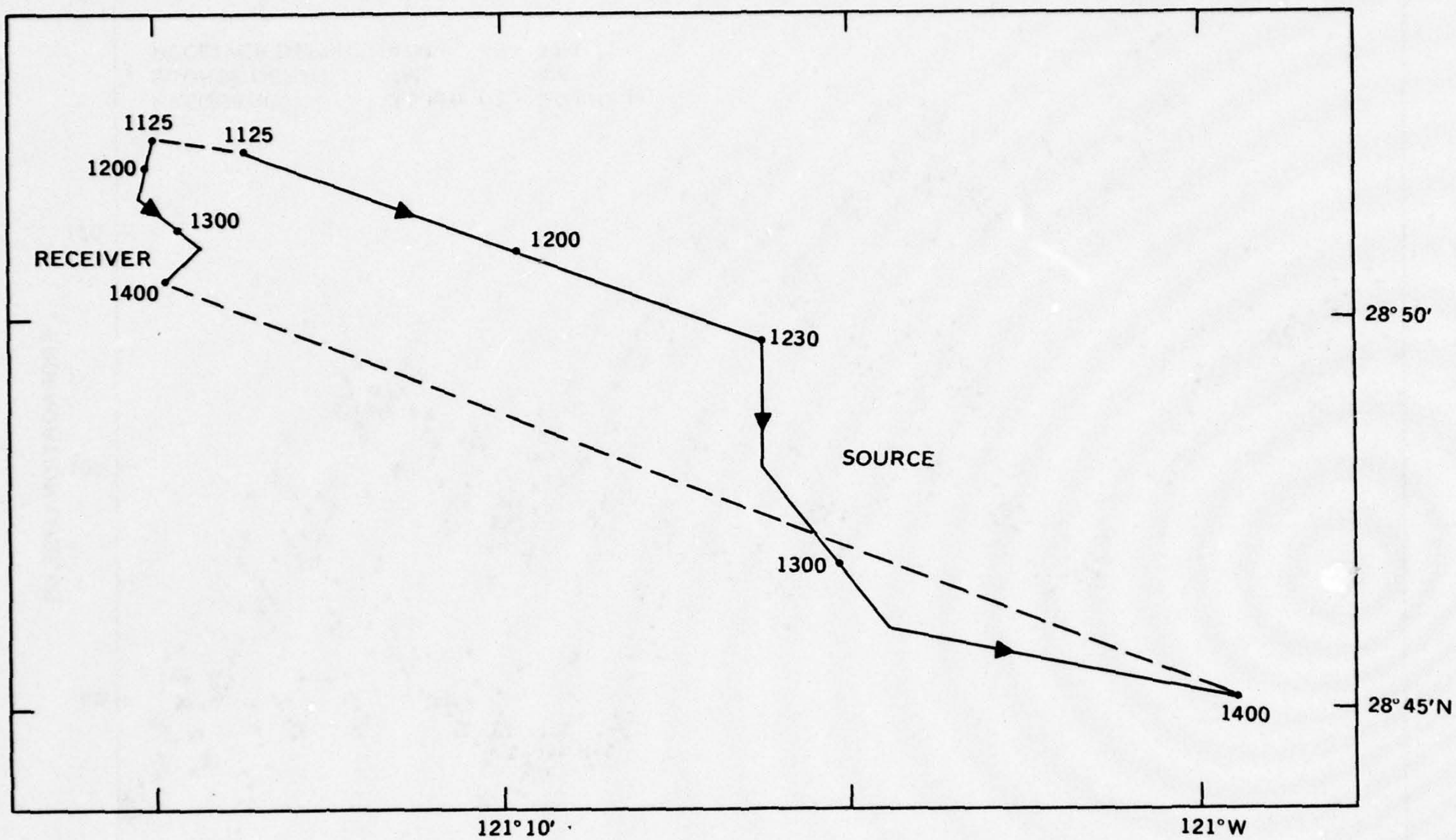


Figure 19. Station 1, run 5. Tracks of source and receiver ships and 1125 LST and 1400 LST propagation paths.

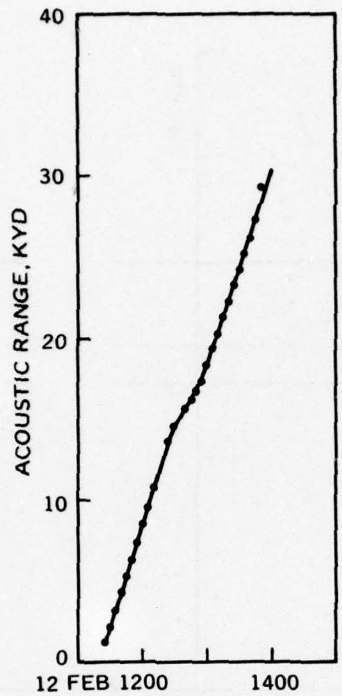


Figure 20. Station 1, run 5. Acoustic range versus time of day (LST).

channel with axis at about 18 m and a 100-m refractive channel with axis at 200-m. No surface channel was present in the average profile. During this run the source ship reported 5-knot winds, 1-ft waves, and 3-ft swell, while the receiver ship reported 7-knot winds, 1-ft waves, and 4-ft swell. Sea-surface roughness measurements were obtained by the Waverider buoy for the complete run. Spectral analysis of these measurements reveals the presence of wind waves with a peak period of 4.2 sec, with most of the sea-surface roughness concentrated in a 12.2- to 15.4-sec wave period band of swell. Receiver 1 was located above the depressed channel in a negative sound-speed gradient, receiver 2 was in the depressed channel, receiver 3 was just under the sound-speed maximum associated with the depressed channel, receiver 4 was in the thermocline, and receiver 5 was about 5 m above the refractive channel.

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements, and applicable to the run 5 experiment are:

number of observations	2421
isothermal layer depth	0 ft
surface water temperature	59.5°F
sea state	2

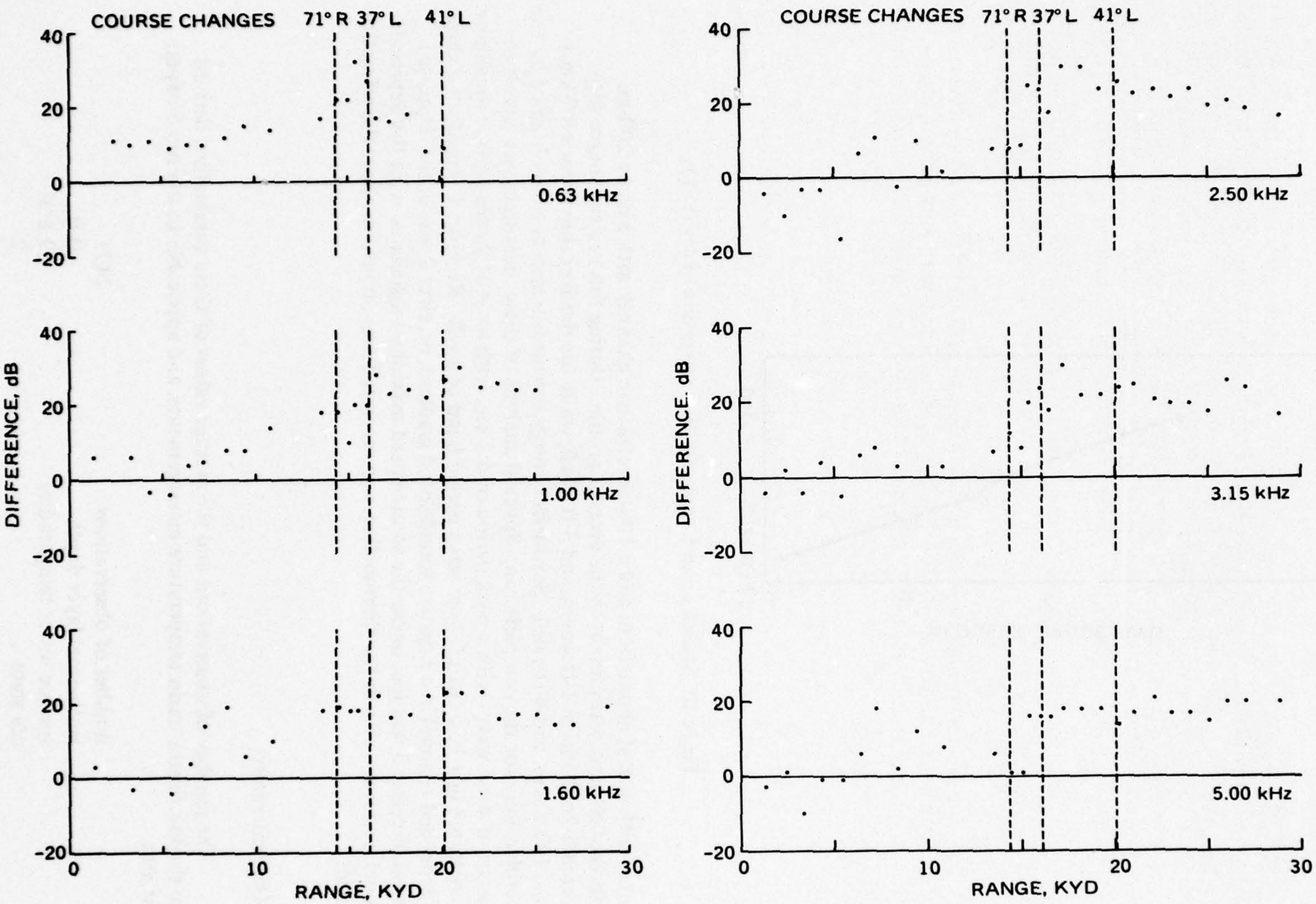


Figure 21. Station 1, run 5. Difference in propagation loss between 57-m and 6-m receivers.

Discussion

The propagation loss measurements are summarized in Appendix E. The data were analyzed with 1/3-octave filters centered at frequencies from 0.4 to 10.0 kHz. Data points not noise limited are plotted as squares on the explosive propagation loss figures, and noise-limited data as open triangles. Noise-limited points represent minimum propagation loss at the plotted range. On these plots the vertical dashed lines indicate the acoustic range at which major source ship course changes of 71 deg to the right and 37 and 41 deg to the left were executed. A visual comparison of these plots suggests the following:

- At all frequencies, except the two lowest (0.40 and 0.63 kHz) and the highest (10.0 kHz), shot arrivals were recorded on all receivers, except the 6-m receiver (1.0 kHz), out to the maximum acoustic range of 28.8 kyd.

- The greatest propagation losses were recorded at 0.40 kHz. At the 6-m receiver, only one non-noise-limited arrival, from 2.4 kyd, was recorded, with only six non-noise-limited arrrivals recorded at the 23-m receiver. The maximum range recorded for non-noise-limited arrivals was 15.5 kyd at 23 m and 57 m, 23.0 kyd at 95 m, and 22.3 kyd at 145 m.

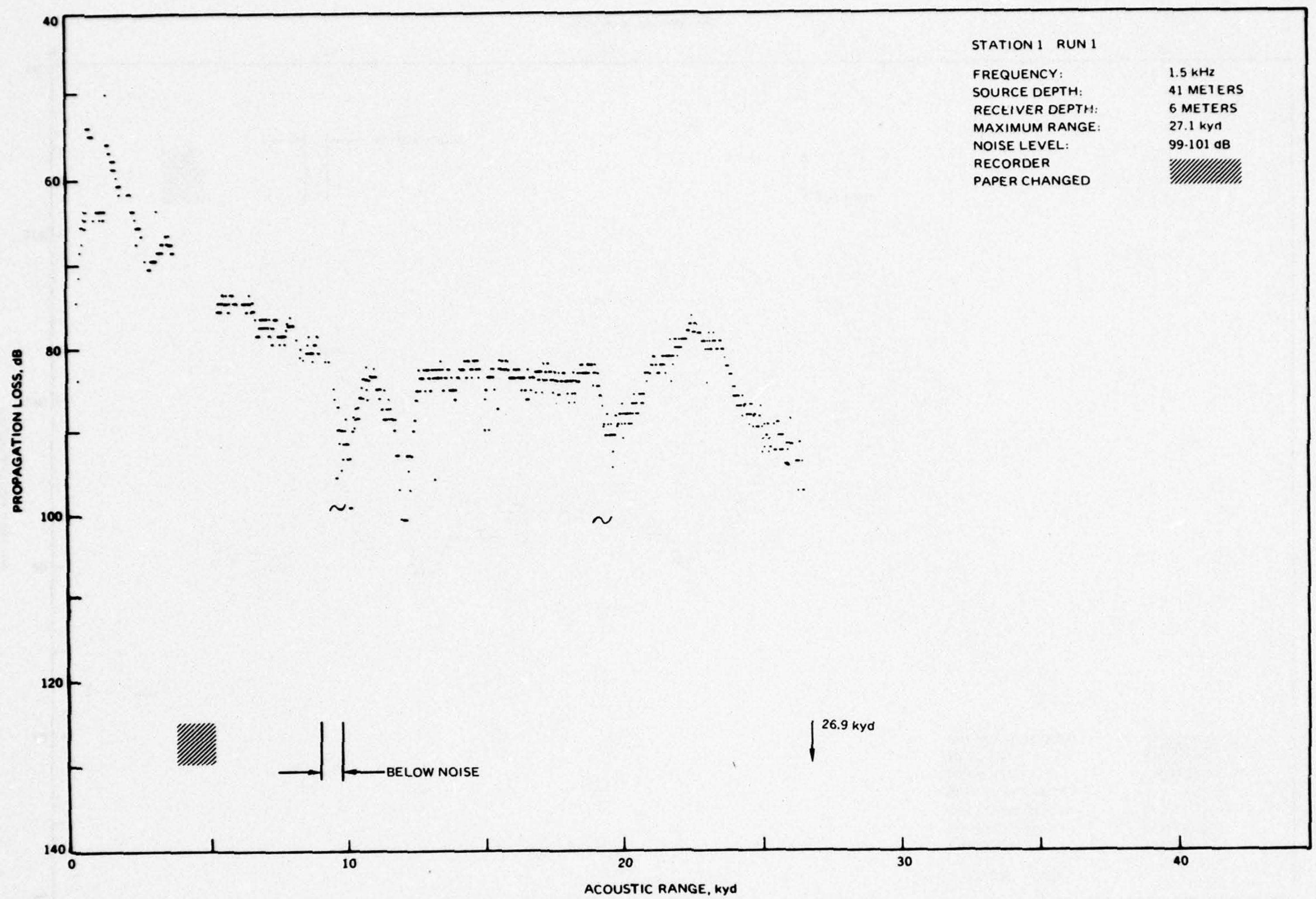
- At all frequencies except 10.0 kHz, the lowest propagation losses were recorded at the 57-m receiver and the greatest at the 6-m receiver. Figure 21 is a plot of the propagation loss difference between the 57- and 6-m receivers for all frequencies except 0.40 and 10.0 kHz. The propagation loss recorded on the 57-m receiver is less than that recorded on the 6-m receiver if the difference is positive. The vertical dashed lines indicate the ranges at which the major source ship course changes occurred. For ranges greater than about 15.0 kyd, the differences are a nominal 20 dB. This range closely coincides with the range of the first major course change. Whether this is causal or coincidental is not known. At ranges less than about 15.0 kyd, the differences are significantly smaller.

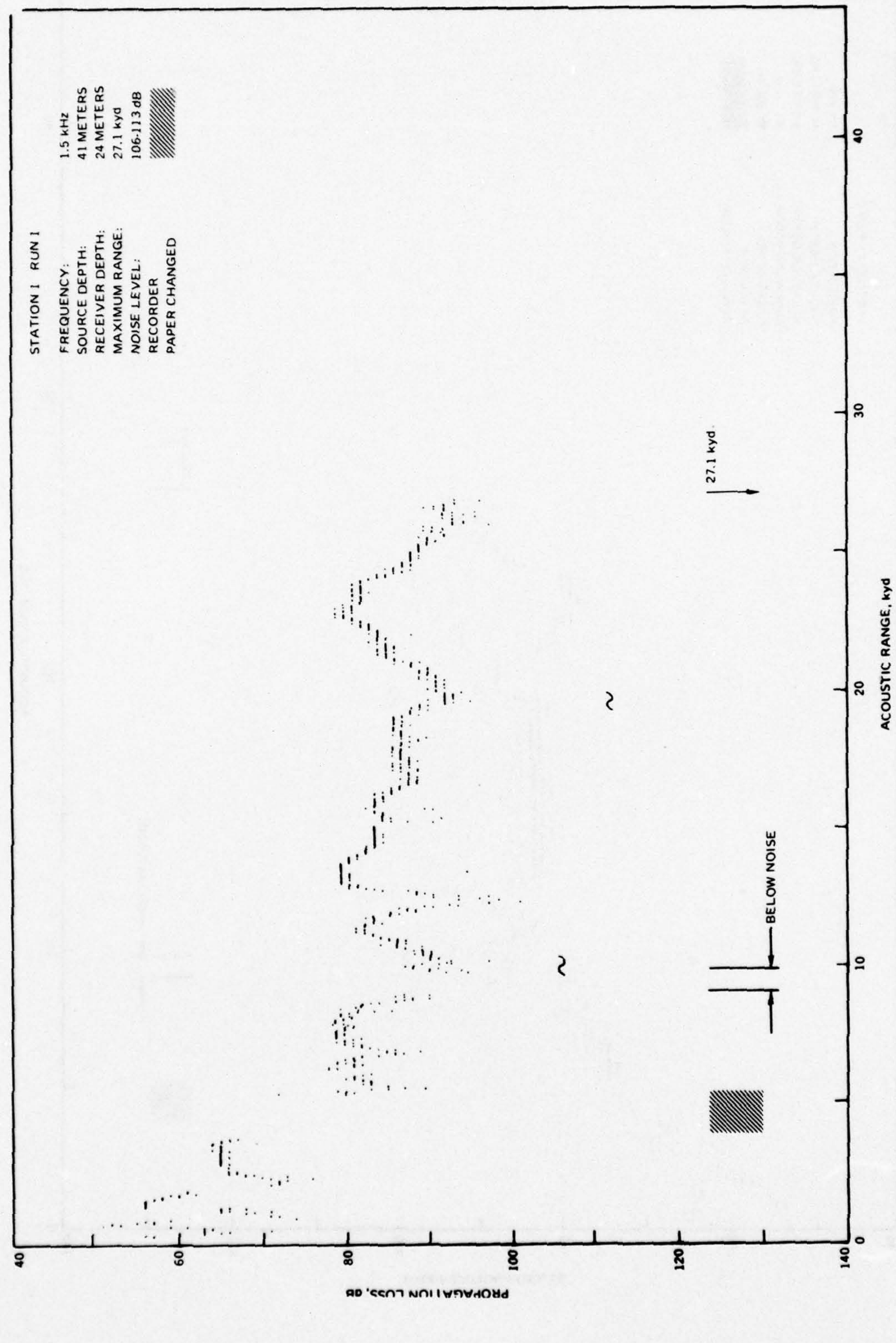
- At 6 m there were no consistent differences among the seven frequencies between 0.63 and 10.0 kHz. At 23 m, the propagation loss is largest at 10.0 kHz, with little consistent difference among the six frequencies between 0.63 and 5.0 kHz. At 57 m, for ranges greater than about 14.0 kyd, the propagation loss for the four middle frequencies was a nominal 10 dB less than for the two lowest and the two highest frequencies. At 95 and 145 m, the greatest propagation losses occurred at 10.0 kHz. The losses, for ranges greater than about 16 kyd, at 1.0 and 1.6 kHz were about 10 dB less than those recorded at the other frequencies.

APPENDIX A

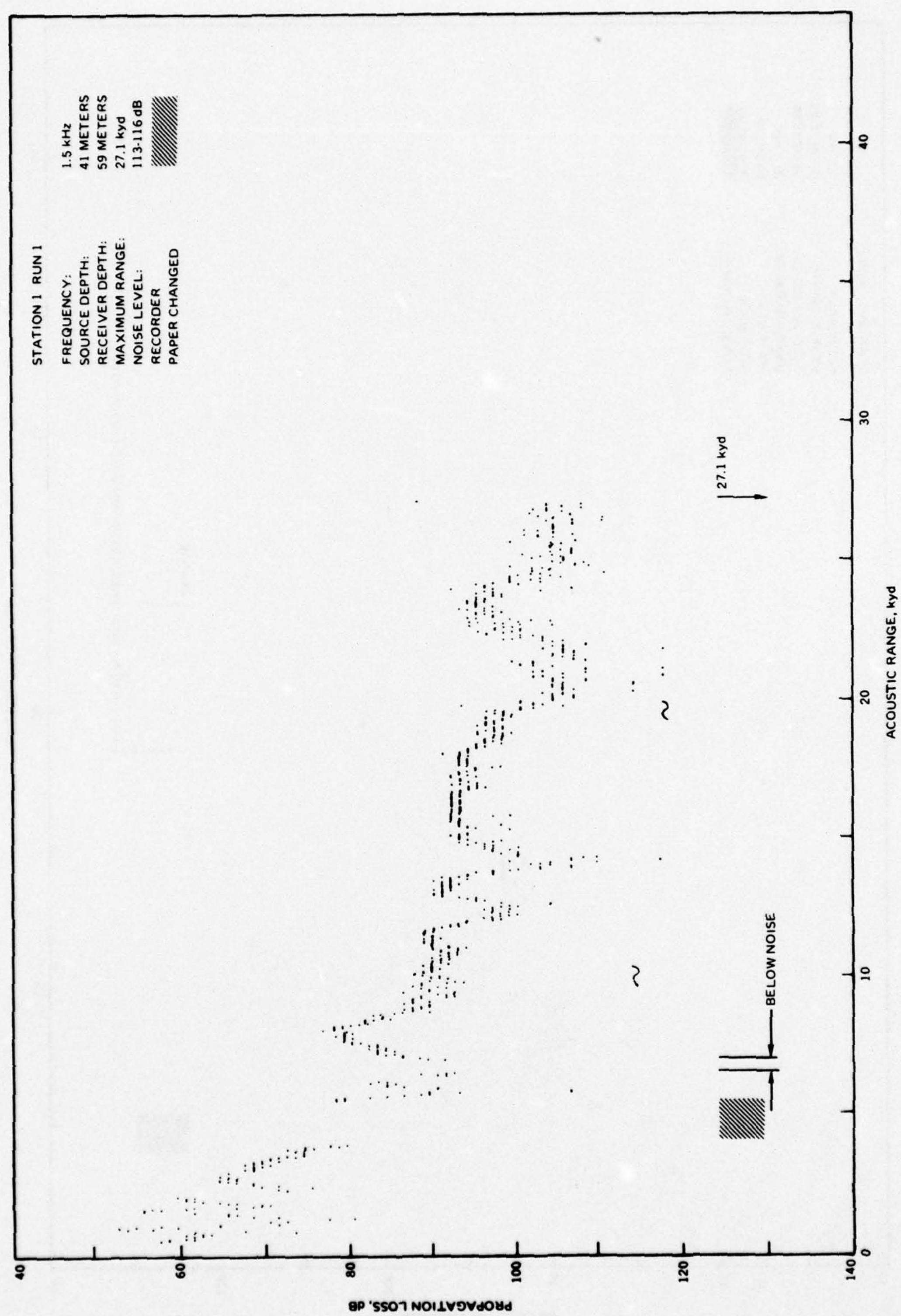
STATION 1 RUN 1

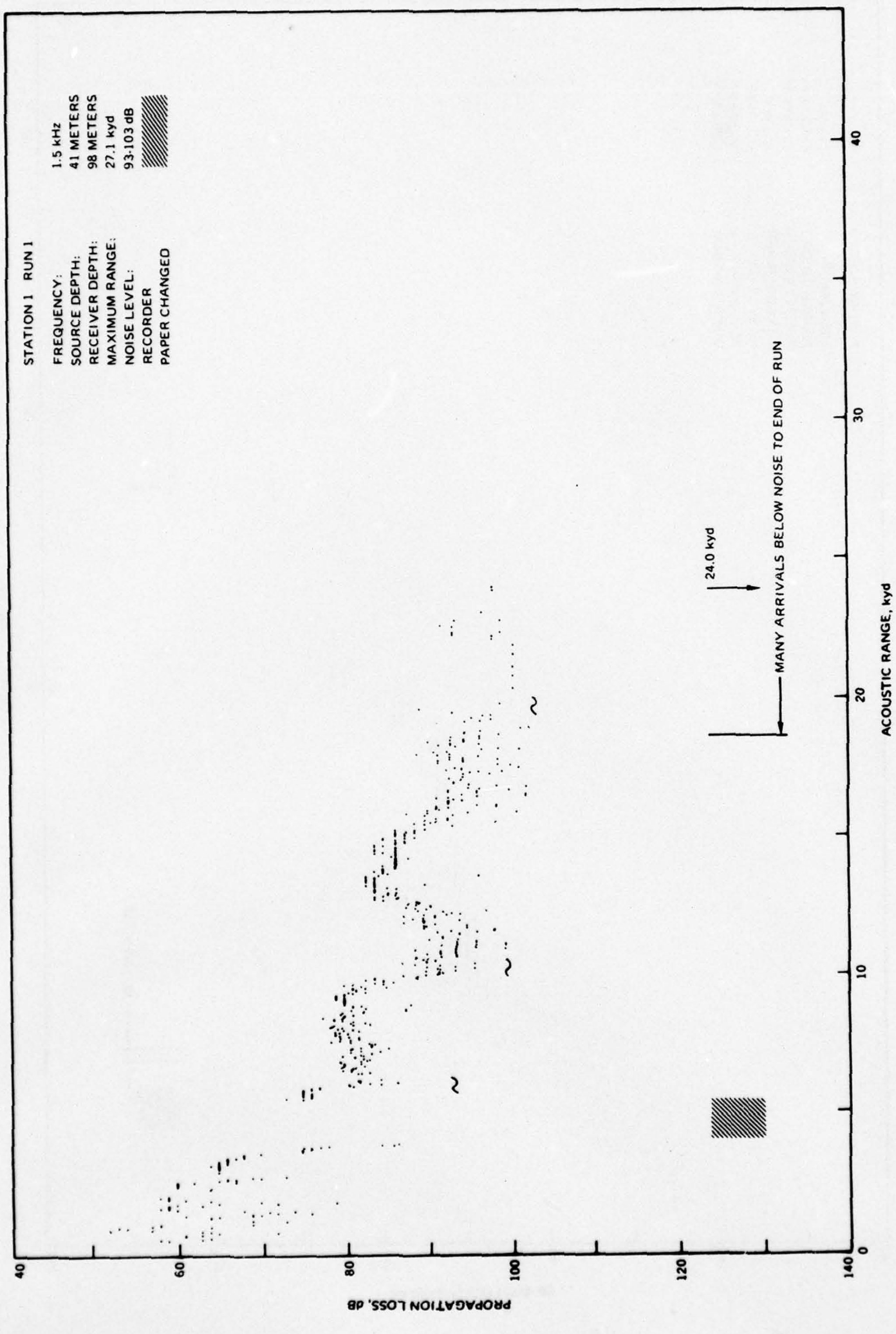
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

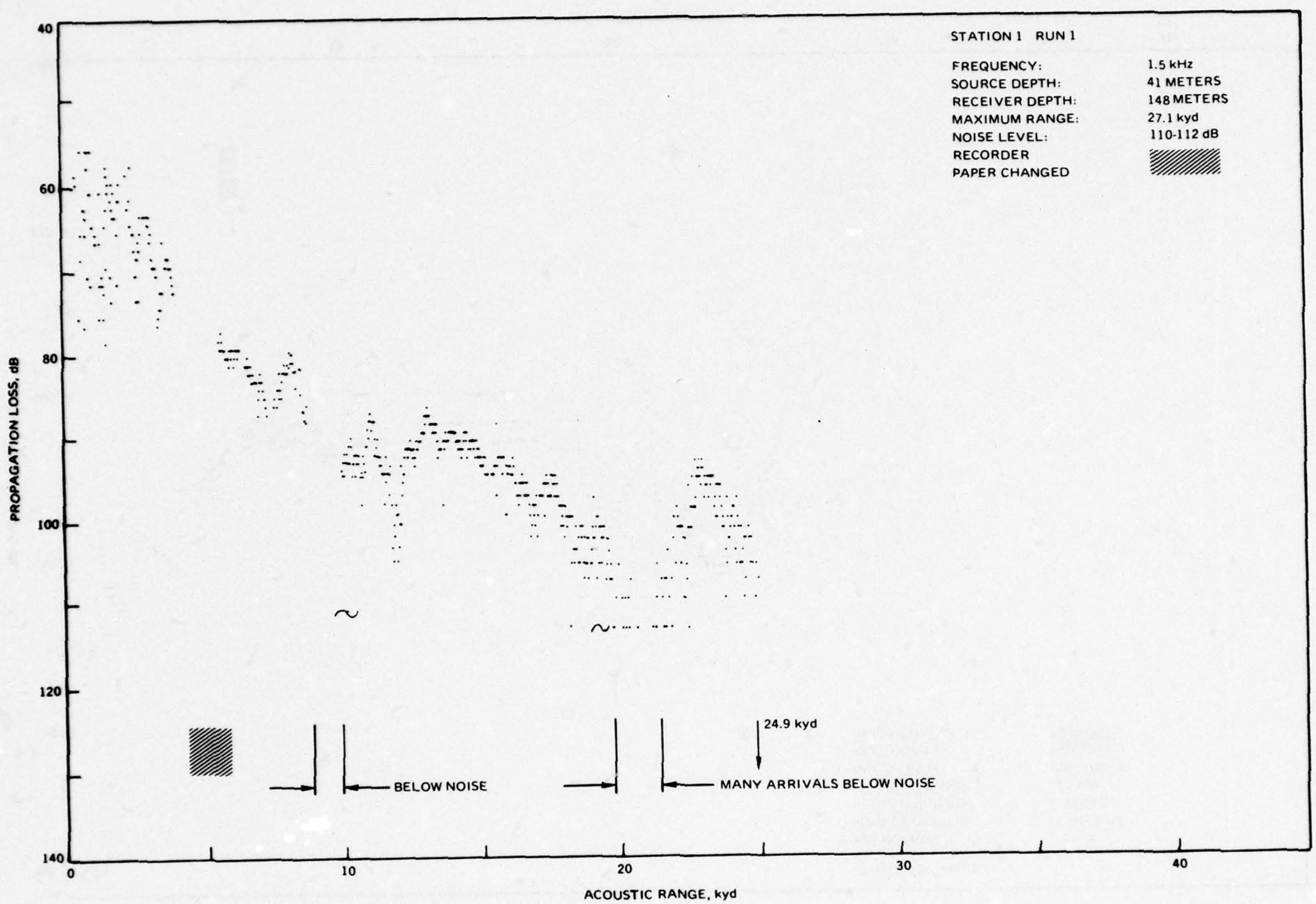

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 99-101 dB
RECORDER PAPER CHANGED
BELOW NOISE
26.9 kyd
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40



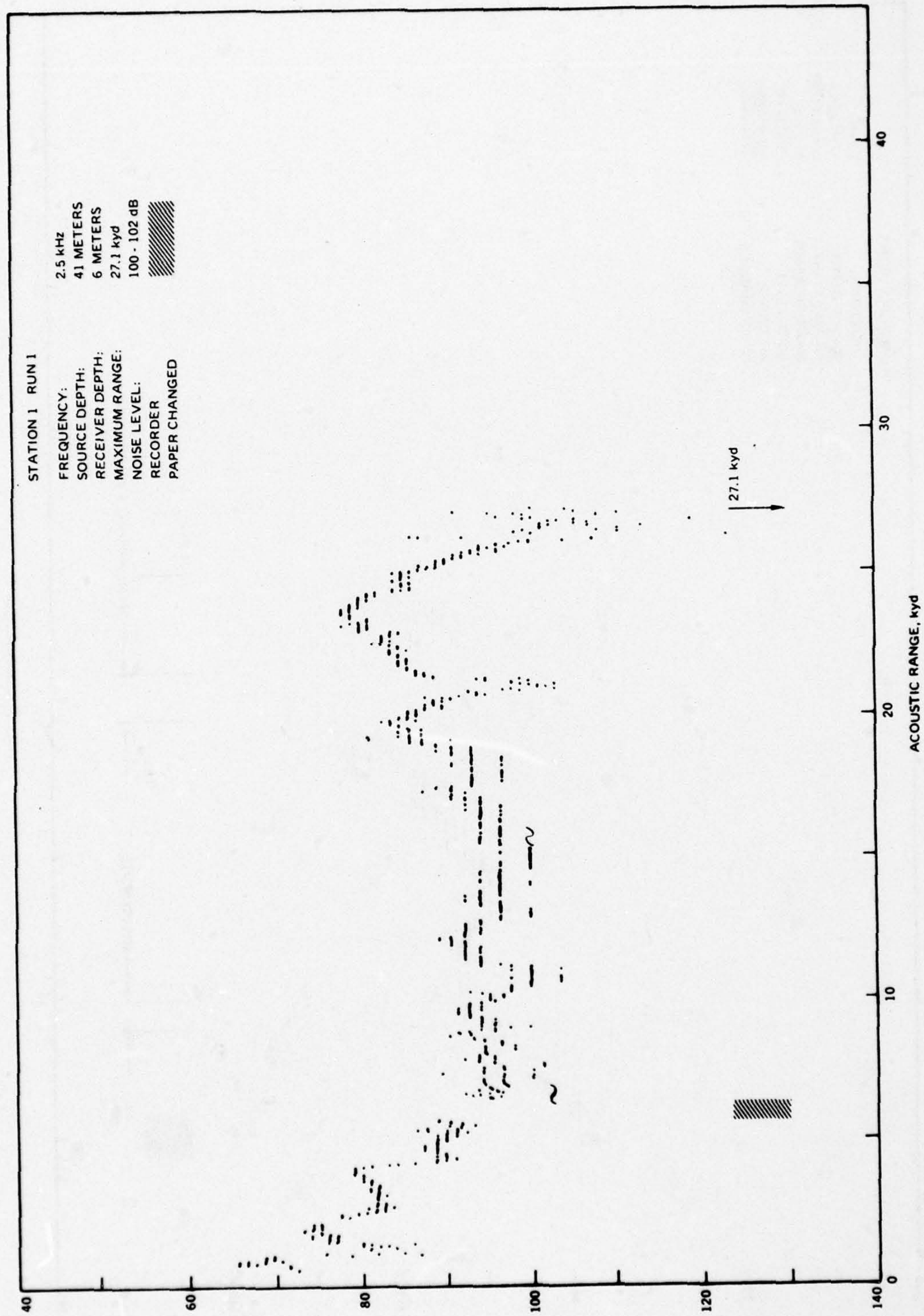
STATION I RUN I
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 24 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 106-113 dB
RECORDER PAPER CHANGED
27.1 kyd
BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

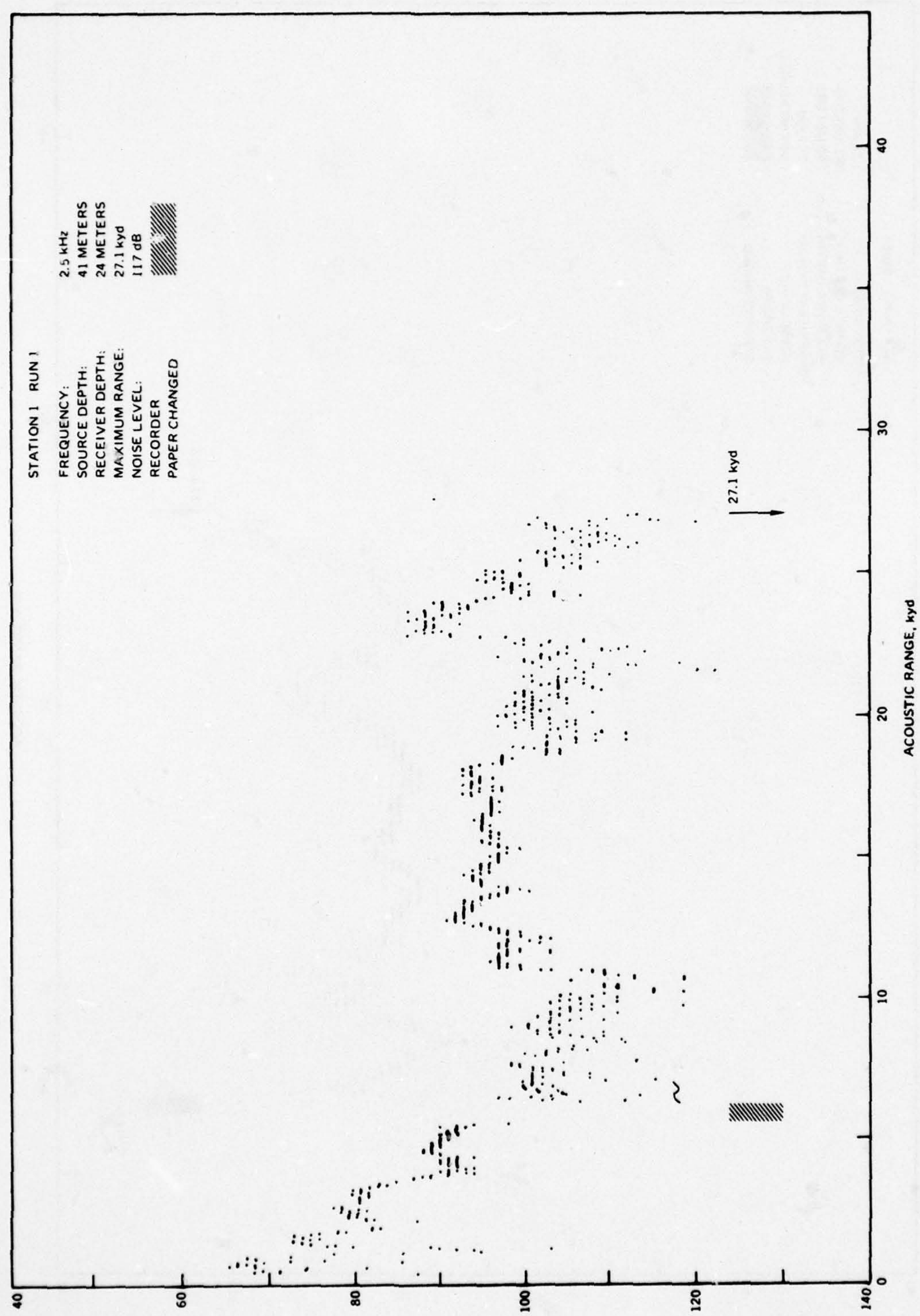

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 59 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 113-116 dB
RECORDER PAPER CHANGED
27.1 kyd
BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

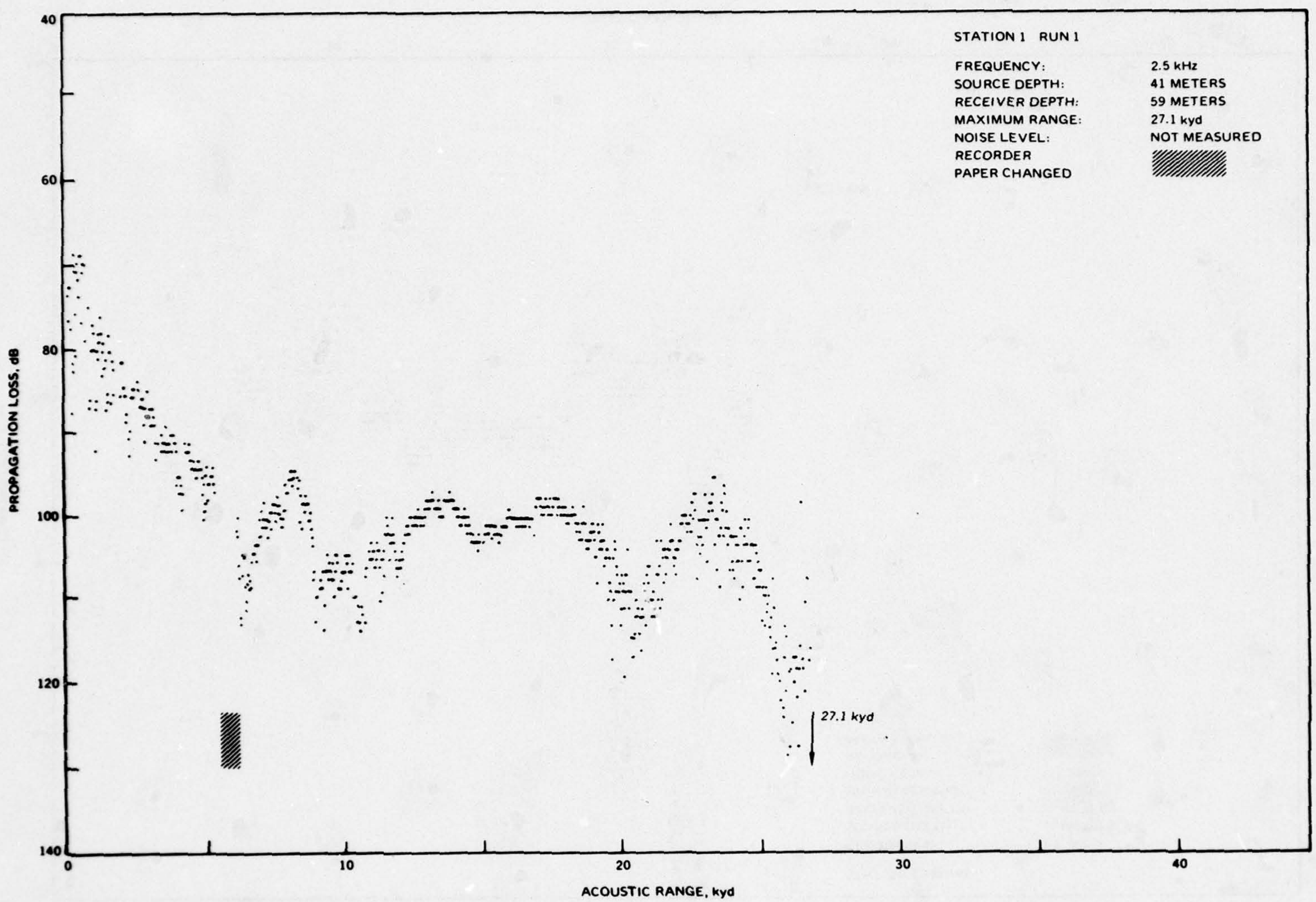

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 98 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 93-103 dB
RECORDER PAPER CHANGED
24.0 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

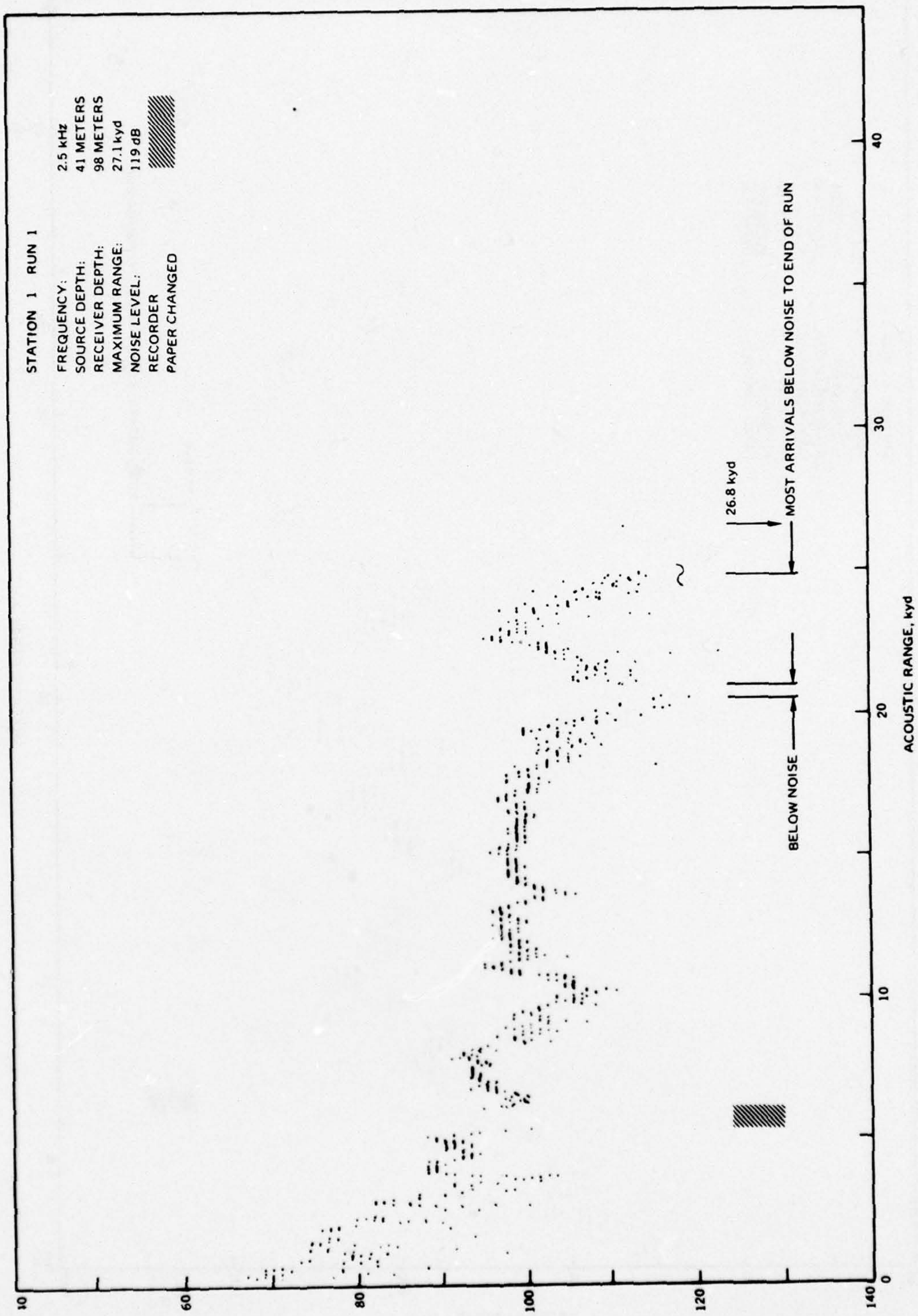


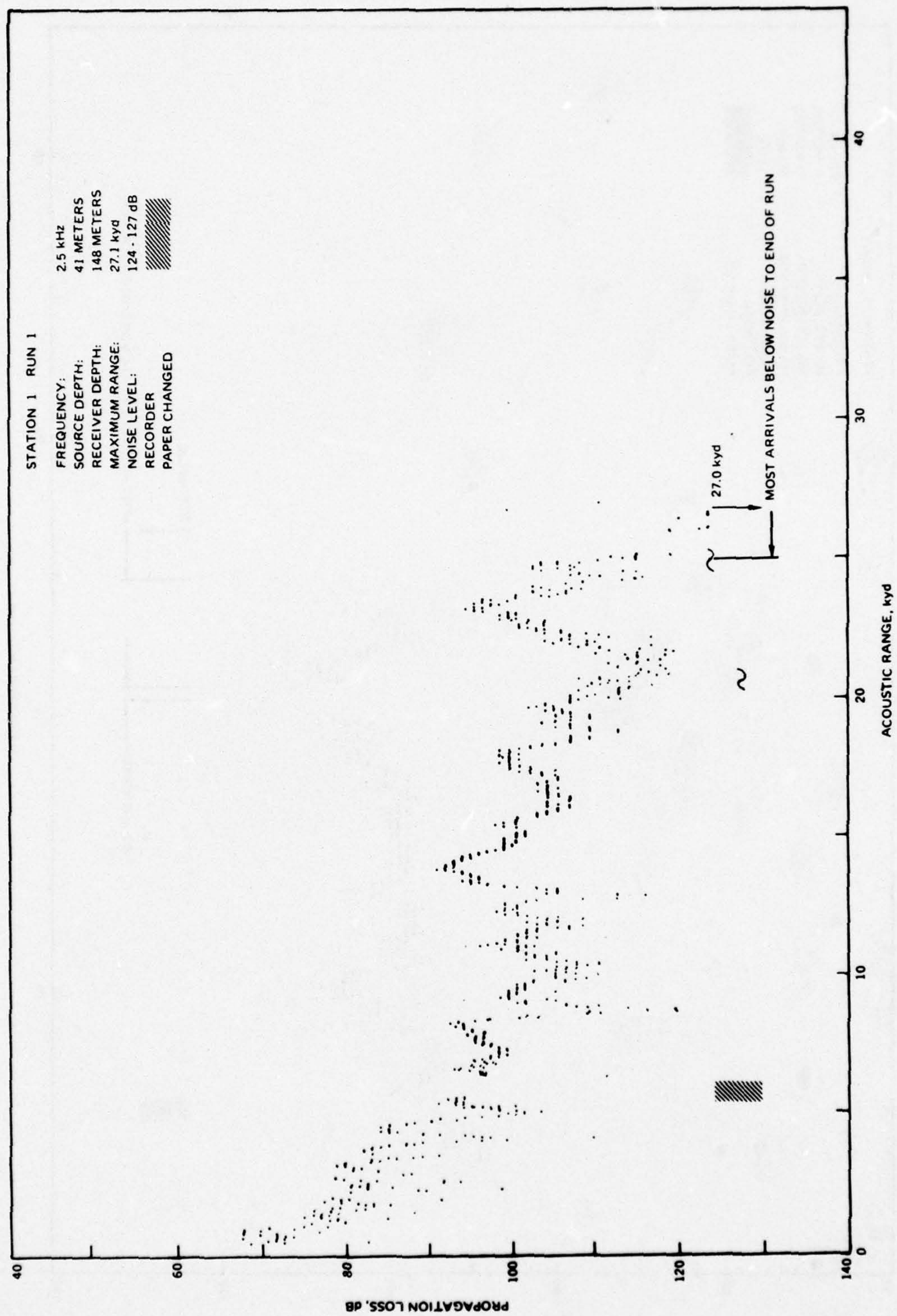
STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 148 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 110-112 dB
RECORDER PAPER CHANGED
24.9 kyd
BELOW NOISE
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd


STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 100 - 102 dB
RECORDER PAPER CHANGED
27.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 24 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 117 dB
RECORDER
PAPER CHANGED
27.1 kyd
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
40
60
80
100
120
140


STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 59 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
27.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 98 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 119 dB
RECORDER PAPER CHANGED
26.8 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
BELOW NOISE
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

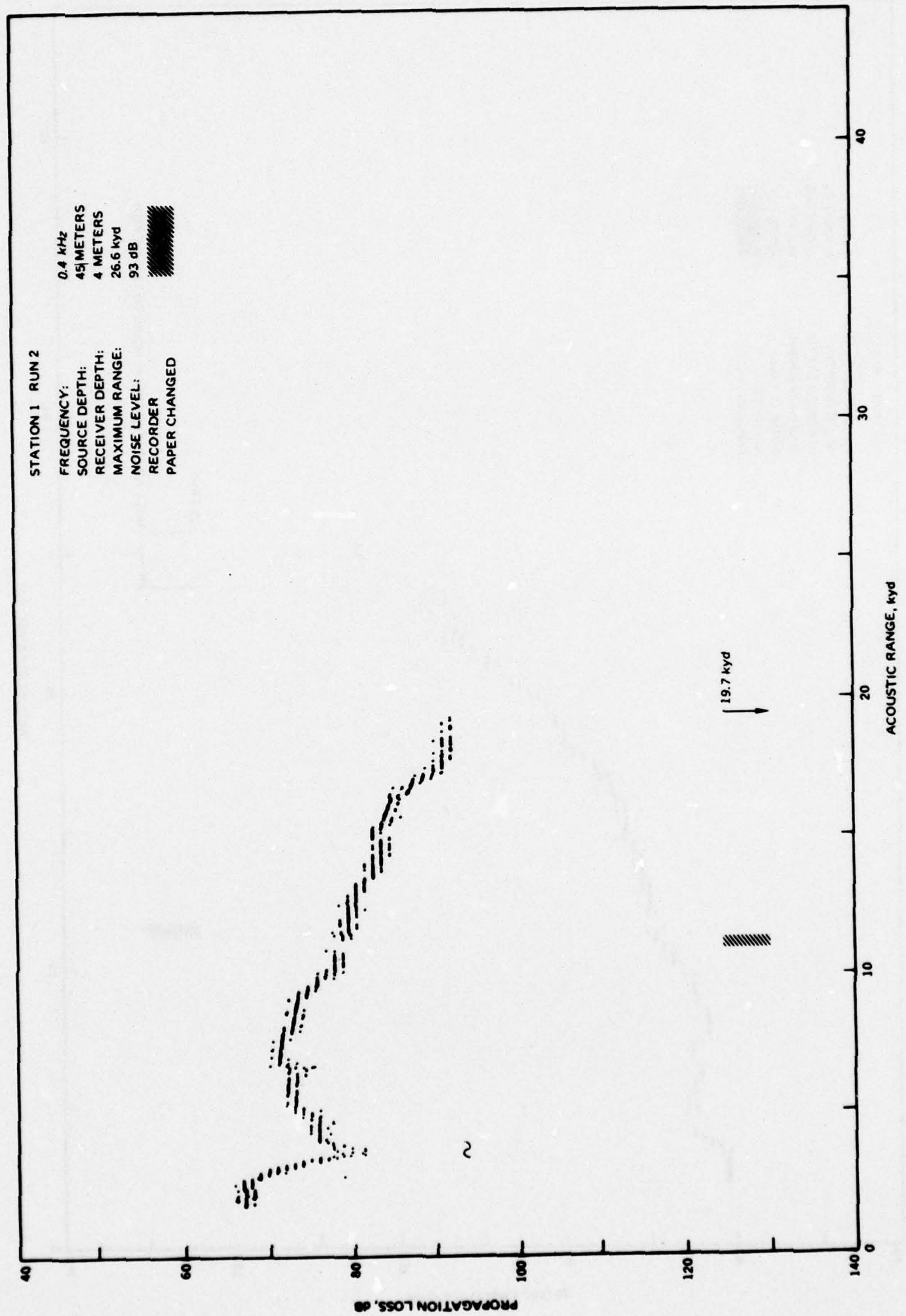


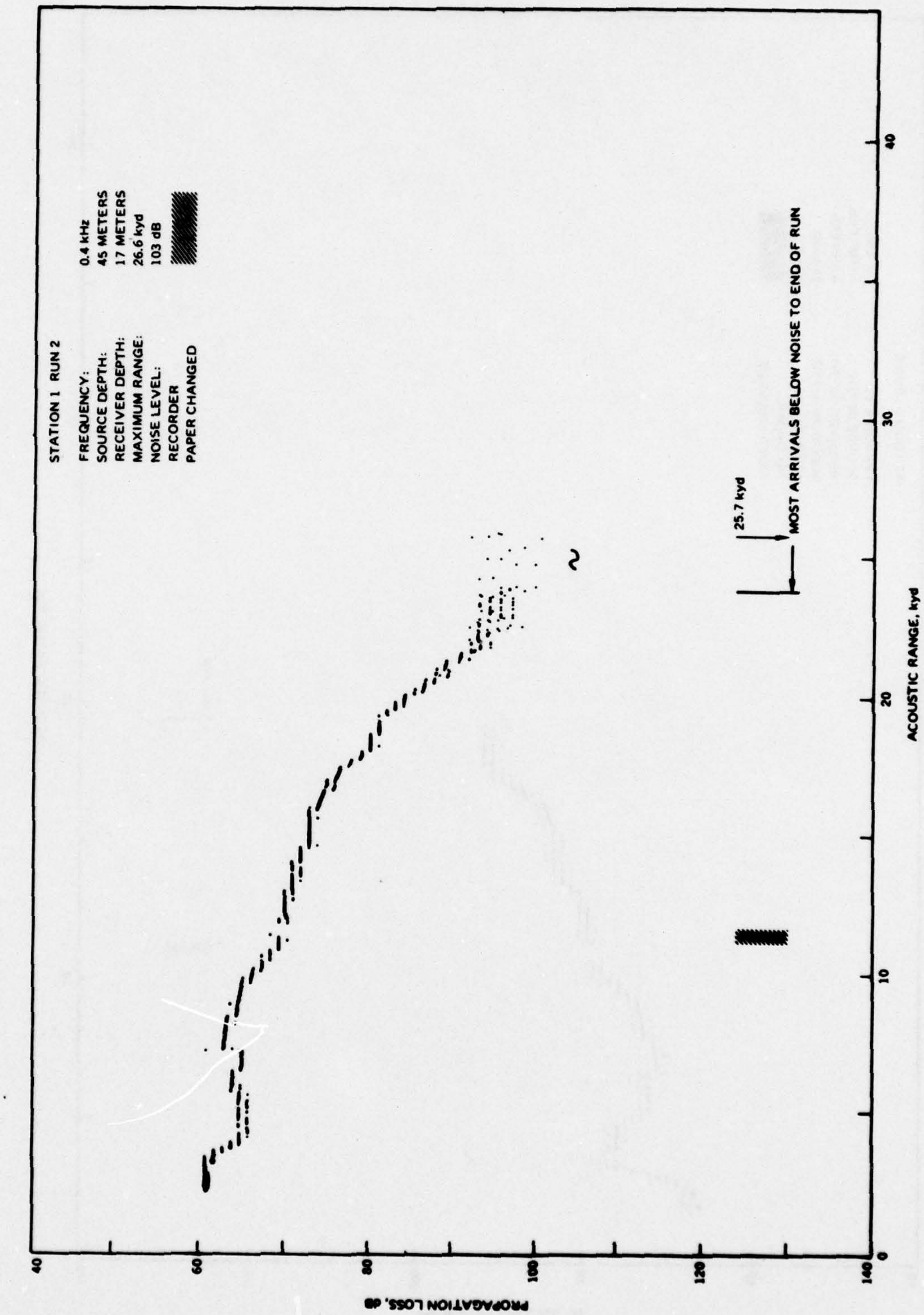
STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 148 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 124 - 127 dB
RECORDER PAPER CHANGED
27.0 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
40
60
80
100
120
140
PROPAGATION LOSS, dB
0
10
20
30
40
ACOUSTIC RANGE, kyd

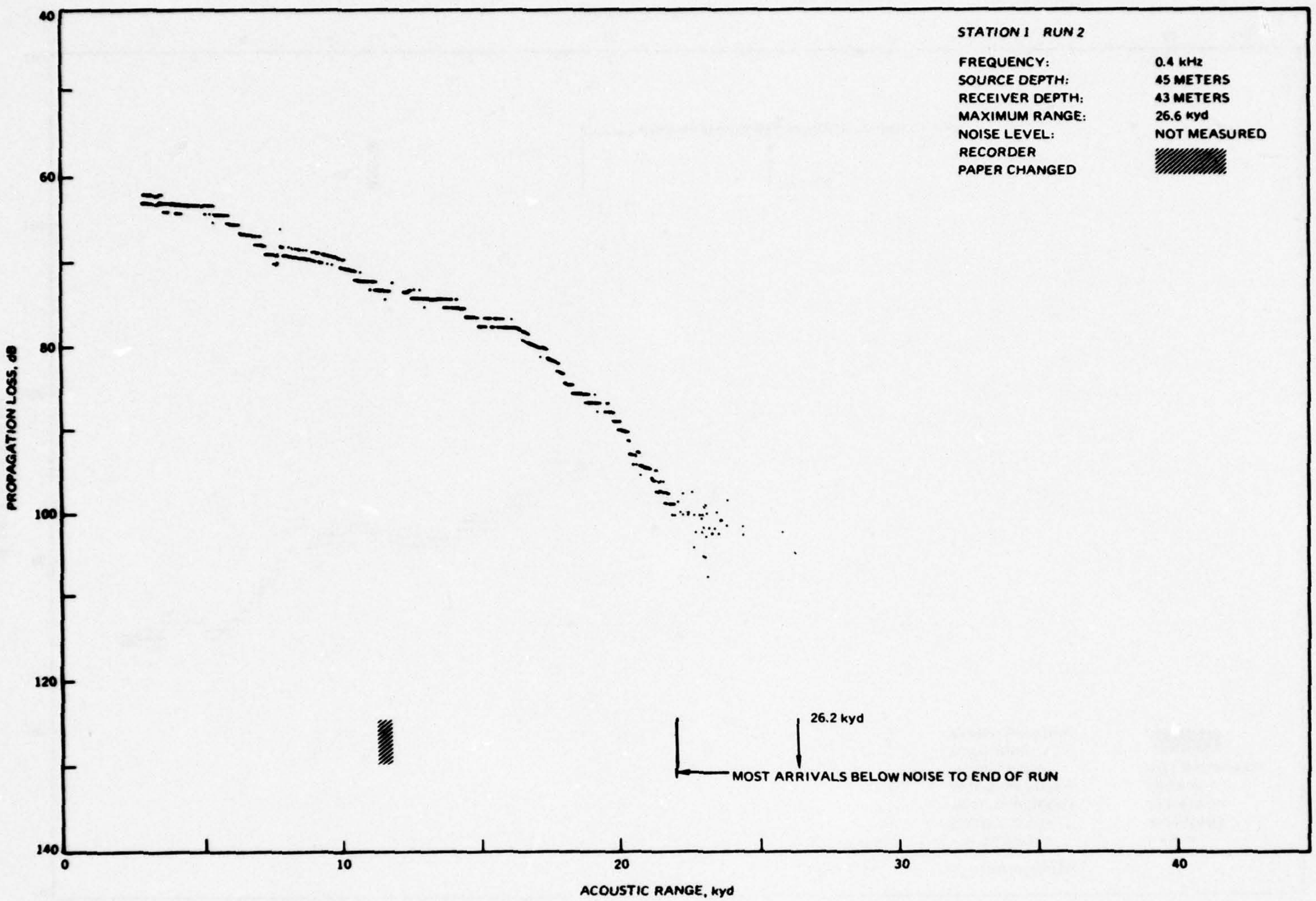
APPENDIX B

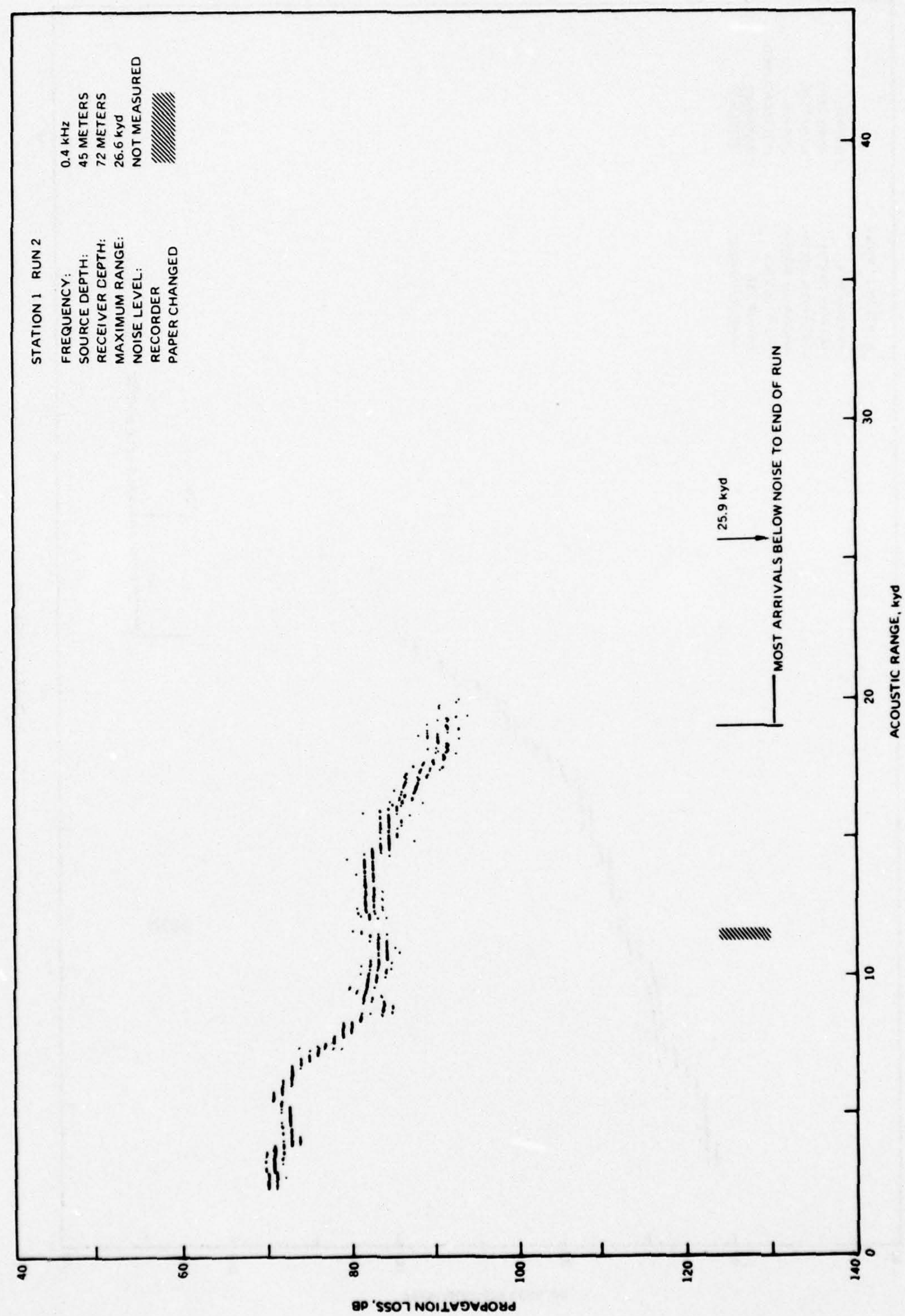
STATION 1 RUN 2

PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

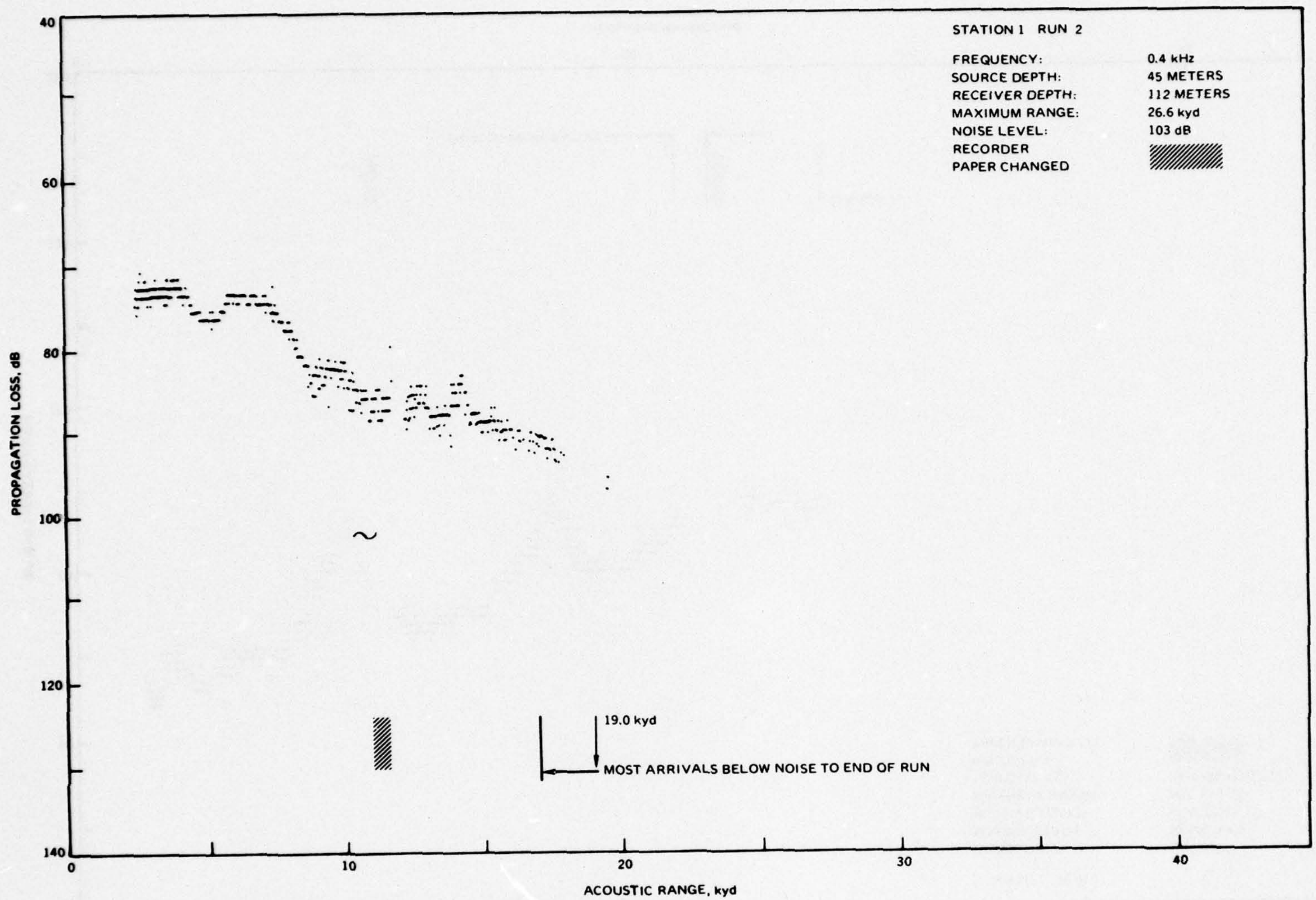

STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 93 dB
RECORDER
PAPER CHANGED
19.7 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 103 dB
RECORDER PAPER CHANGED
25.7 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

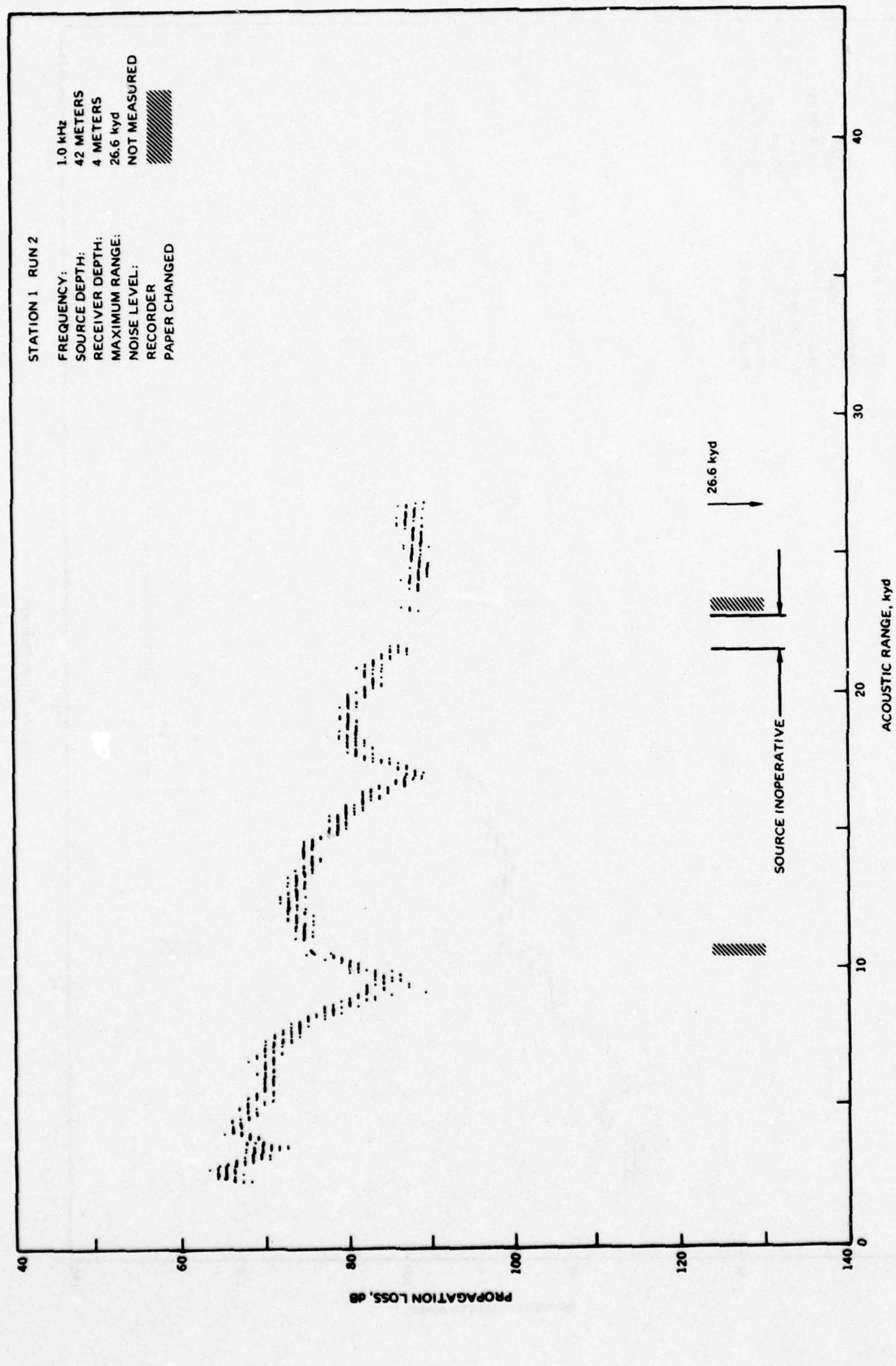

STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
26.2 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

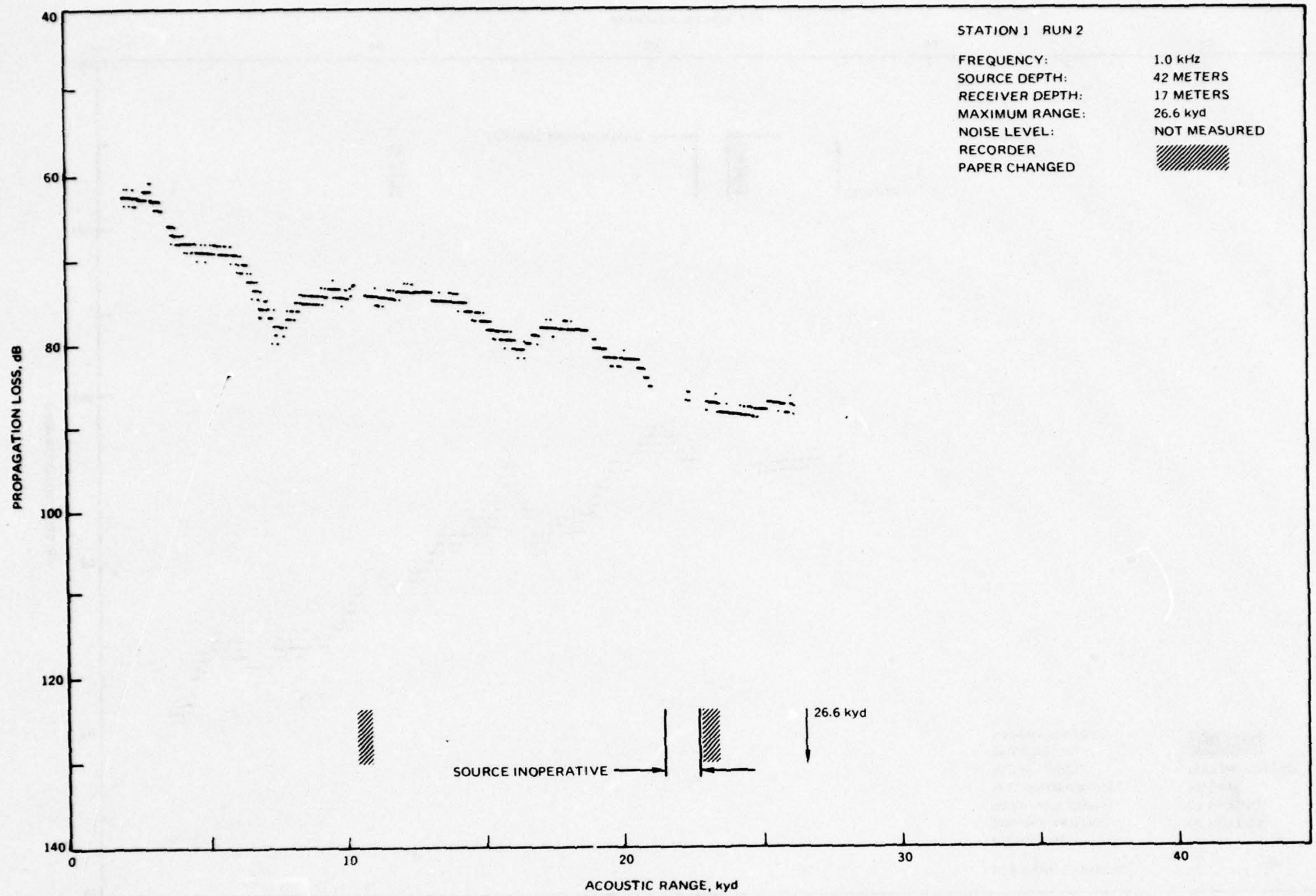


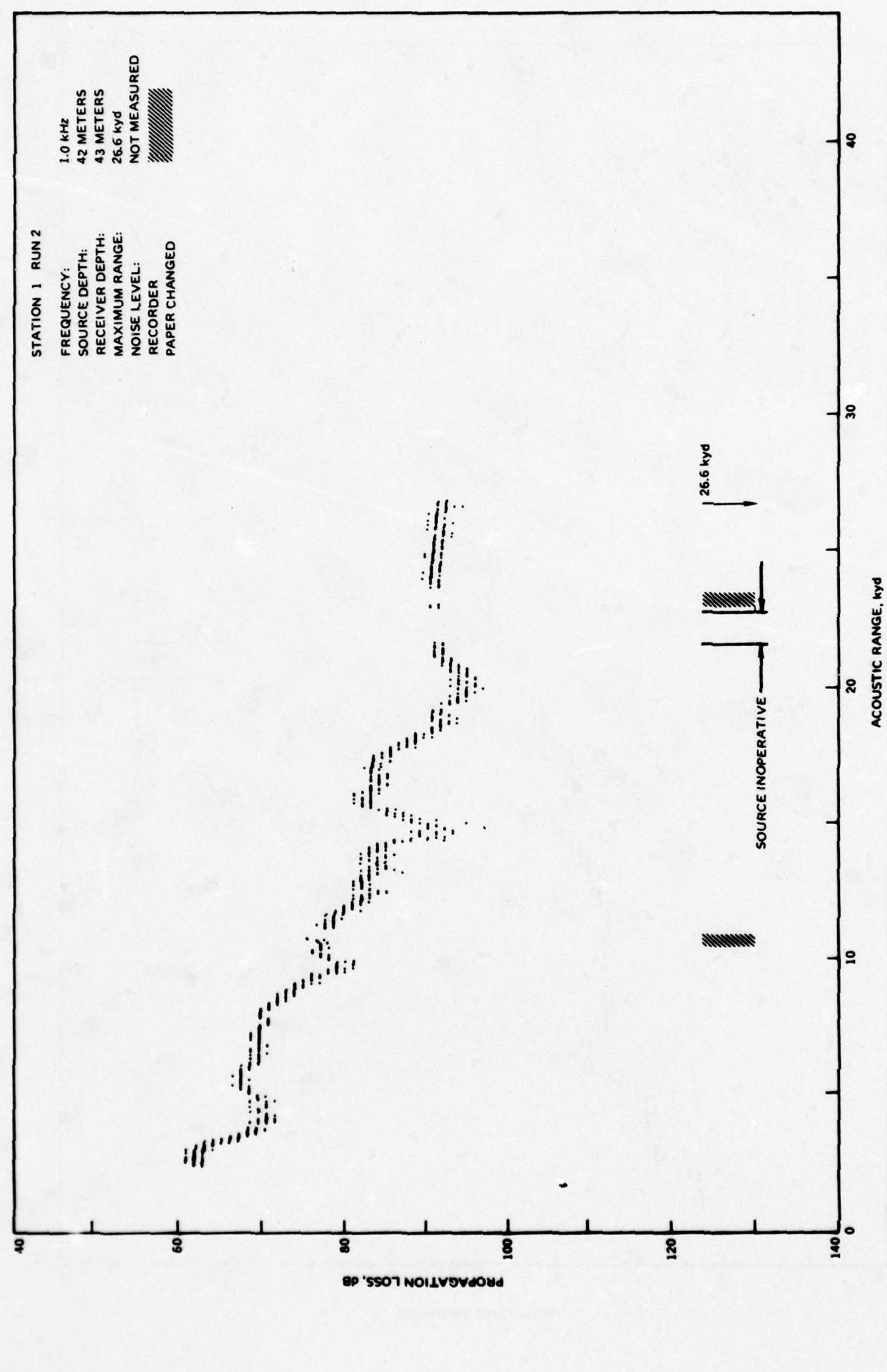
STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
25.9 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
60
80
100
120
140



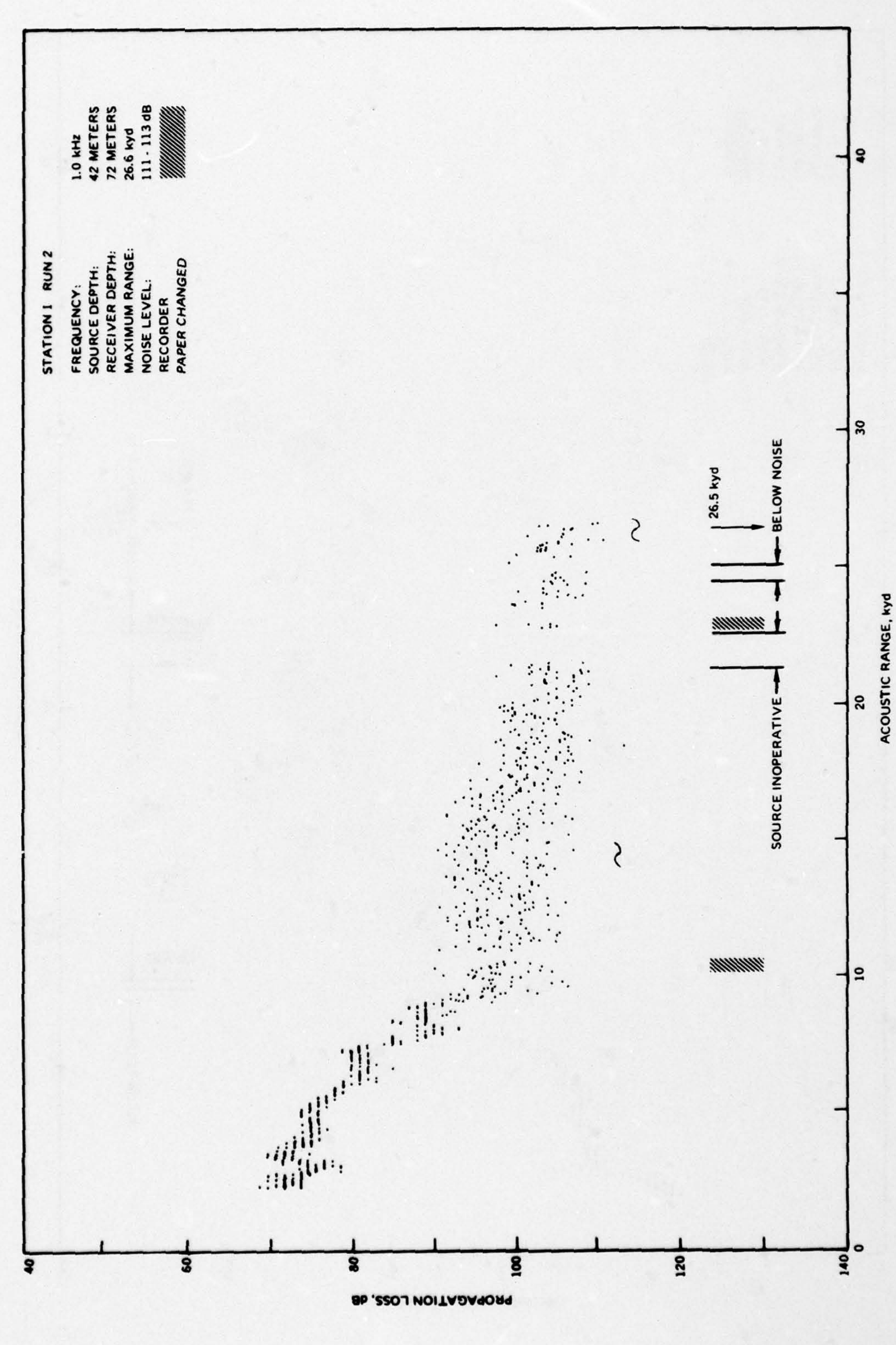
STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 103 dB
RECORDER PAPER CHANGED
19.0 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

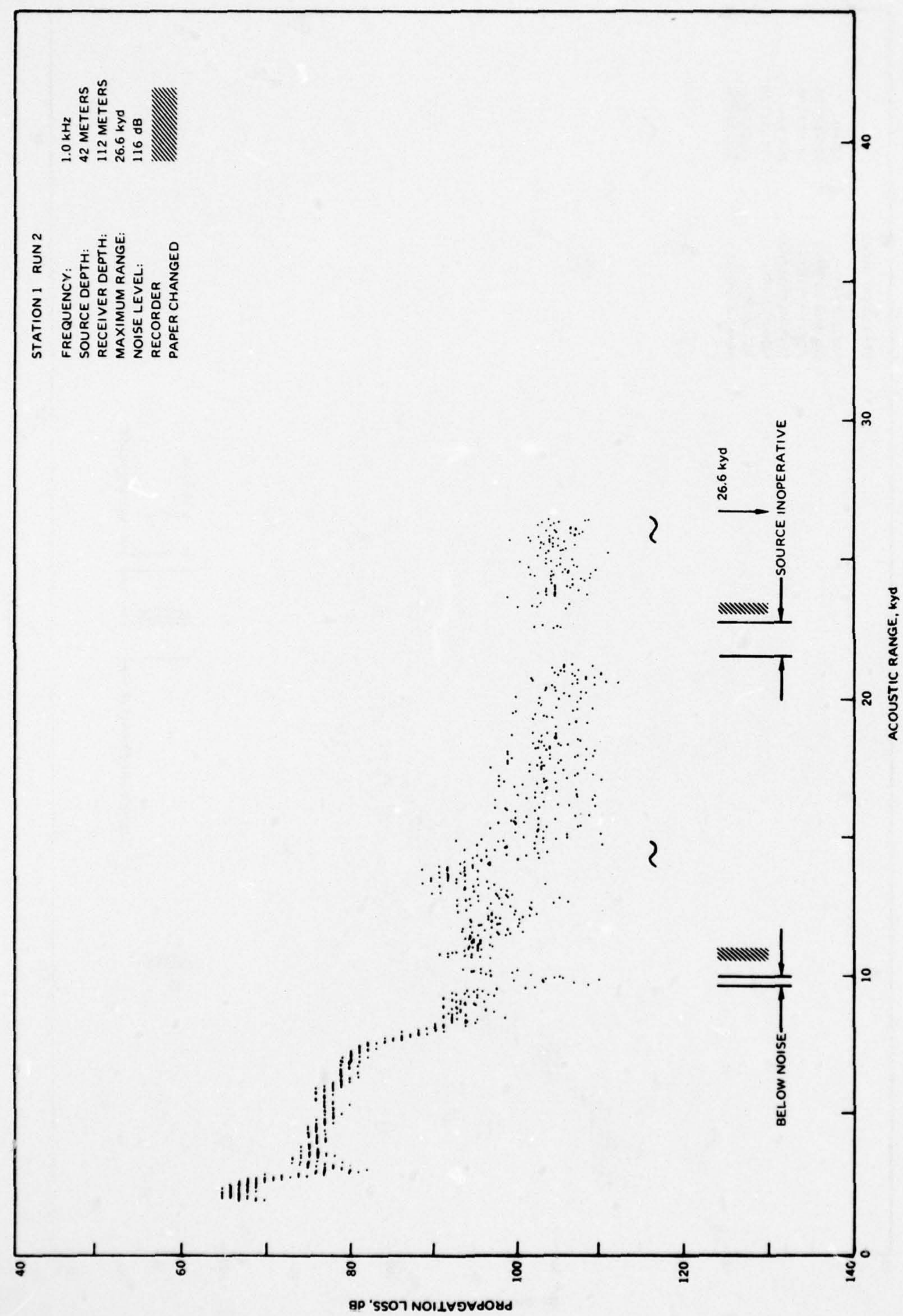

STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER
PAPER CHANGED
26.6 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40


STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
SOURCE INOPERATIVE
26.6 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd



STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
26.6 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

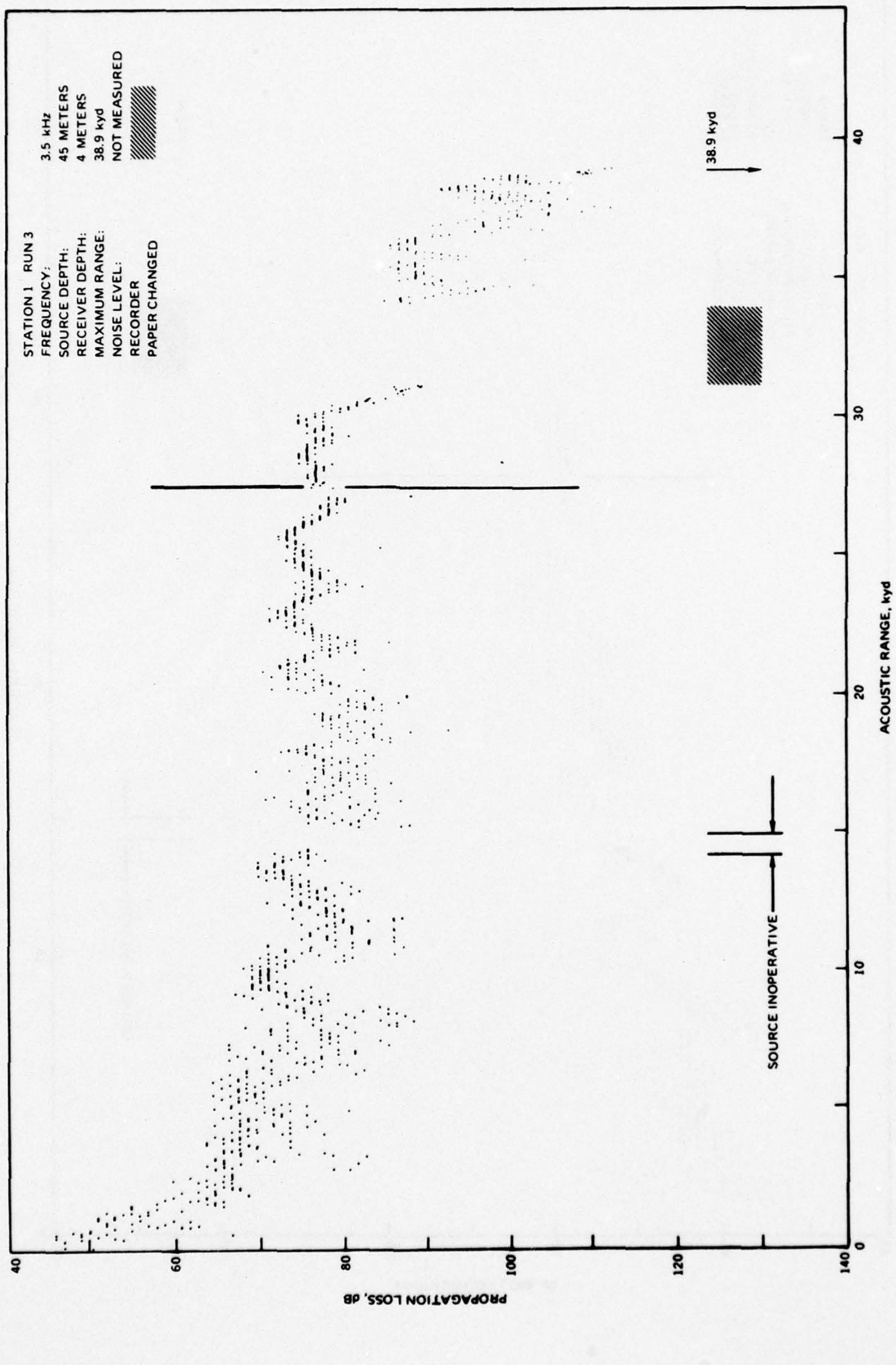

STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 111 - 113 dB
RECORDER PAPER CHANGED
26.5 kyd
BELOW NOISE
SOURCE INOPERATIVE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40

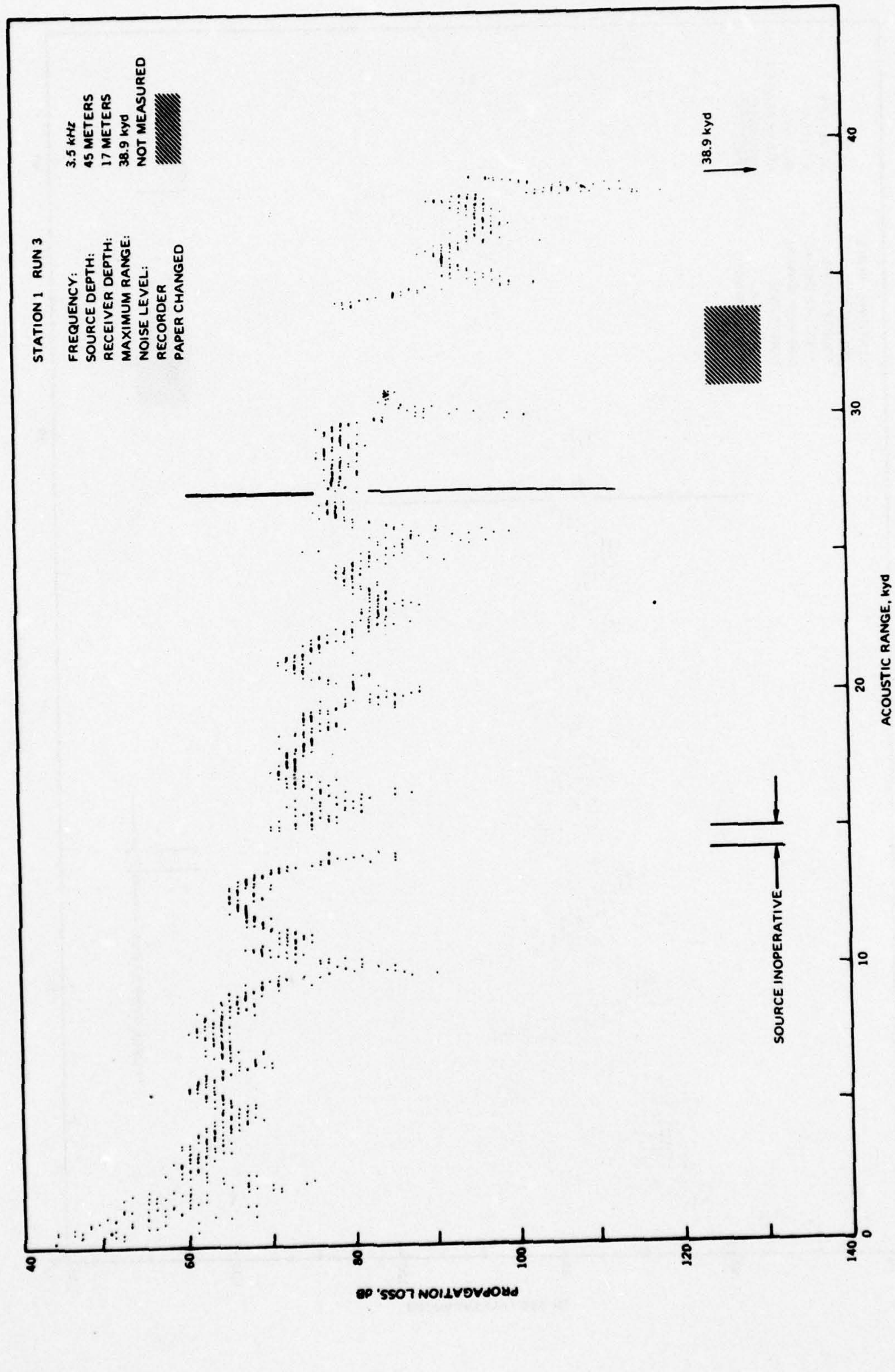

STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 116 dB
RECORDER PAPER CHANGED
BELOW NOISE
SOURCE INOPERATIVE
26.6 kyd
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

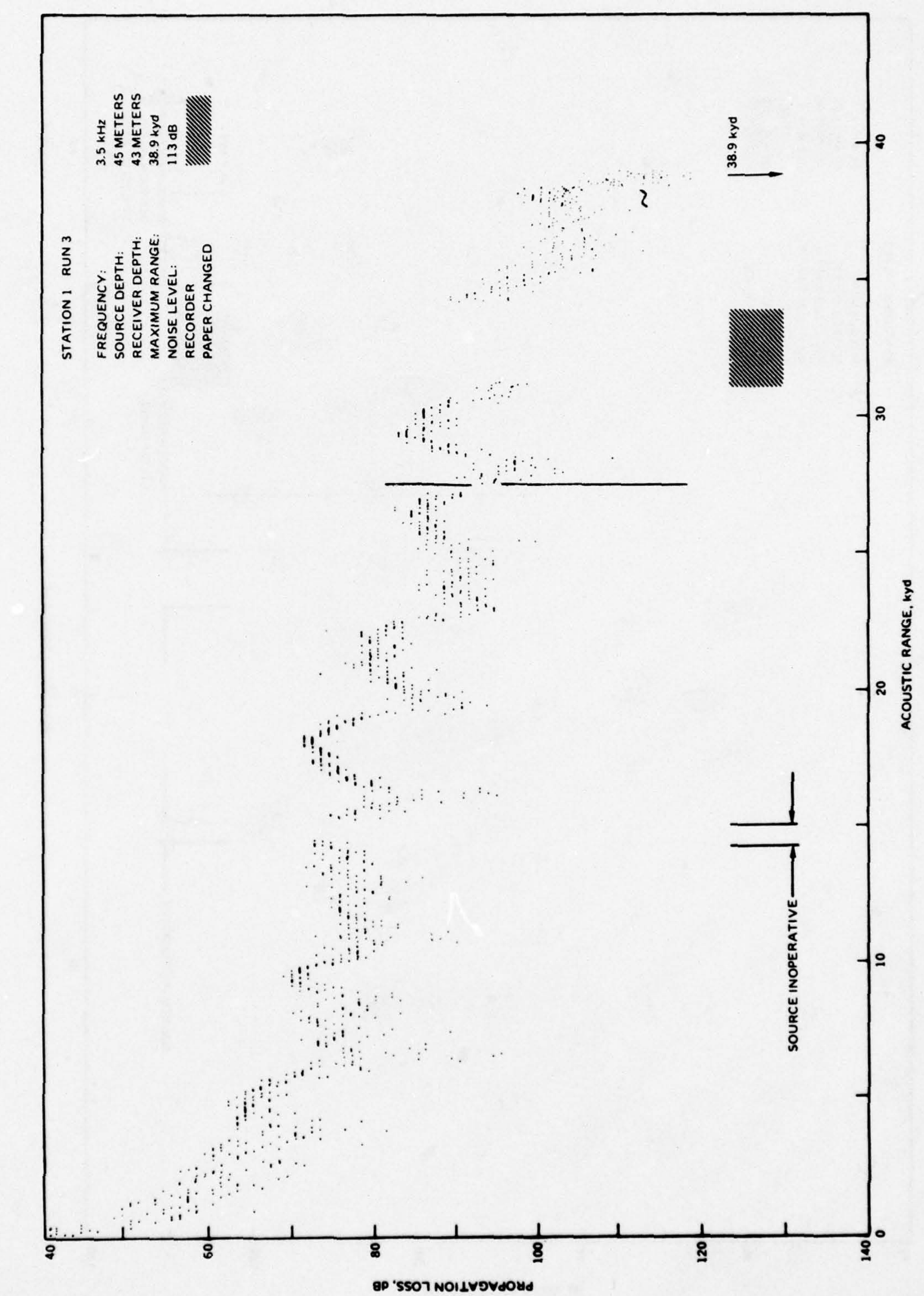
APPENDIX C

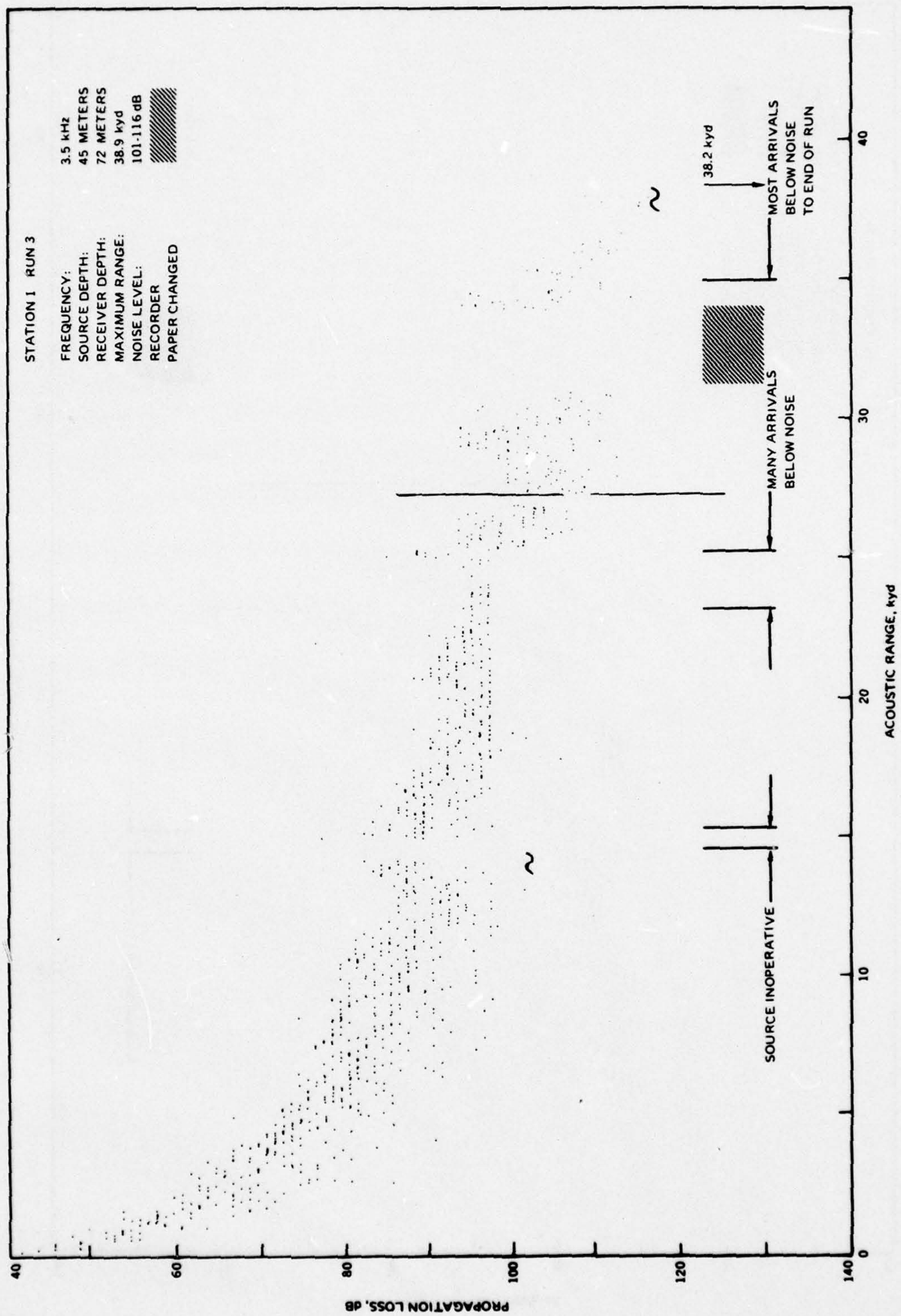
STATION 1 RUN 3

PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

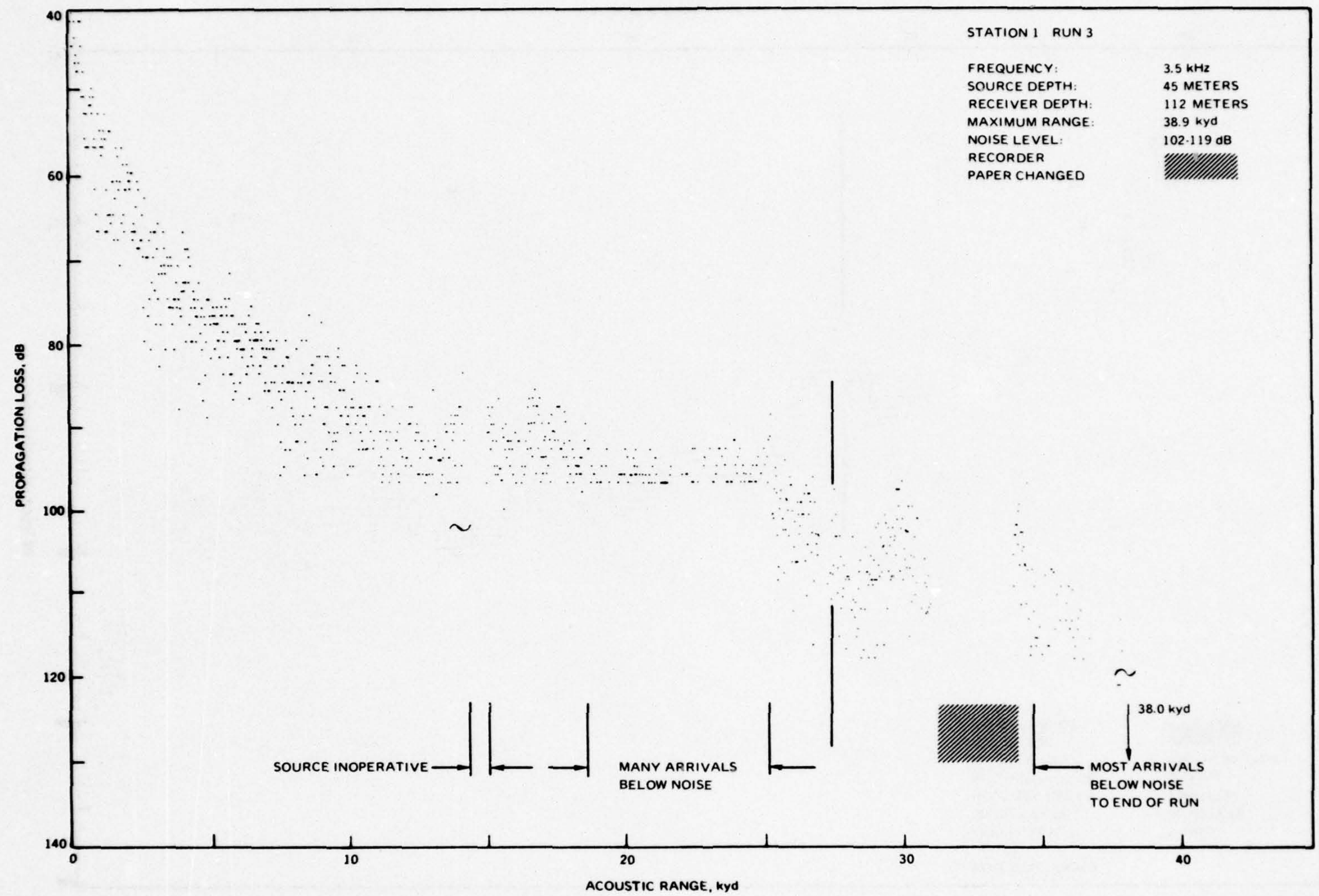

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
38.9 kyd
SOURCE INOPERATIVE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
60
80
100
120
140

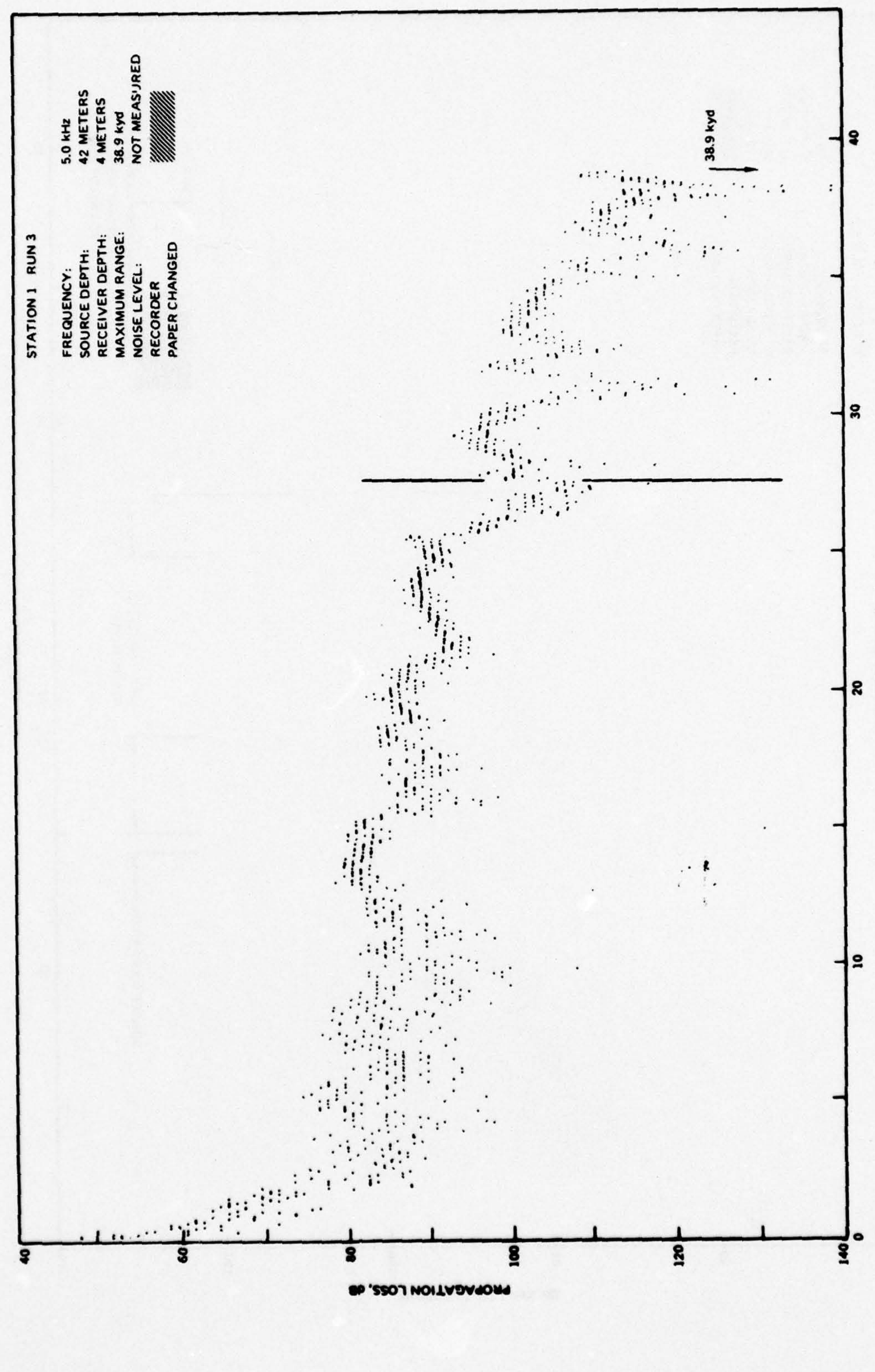

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
38.9 kyd
SOURCE INOPERATIVE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
40
60
80
100
120
140

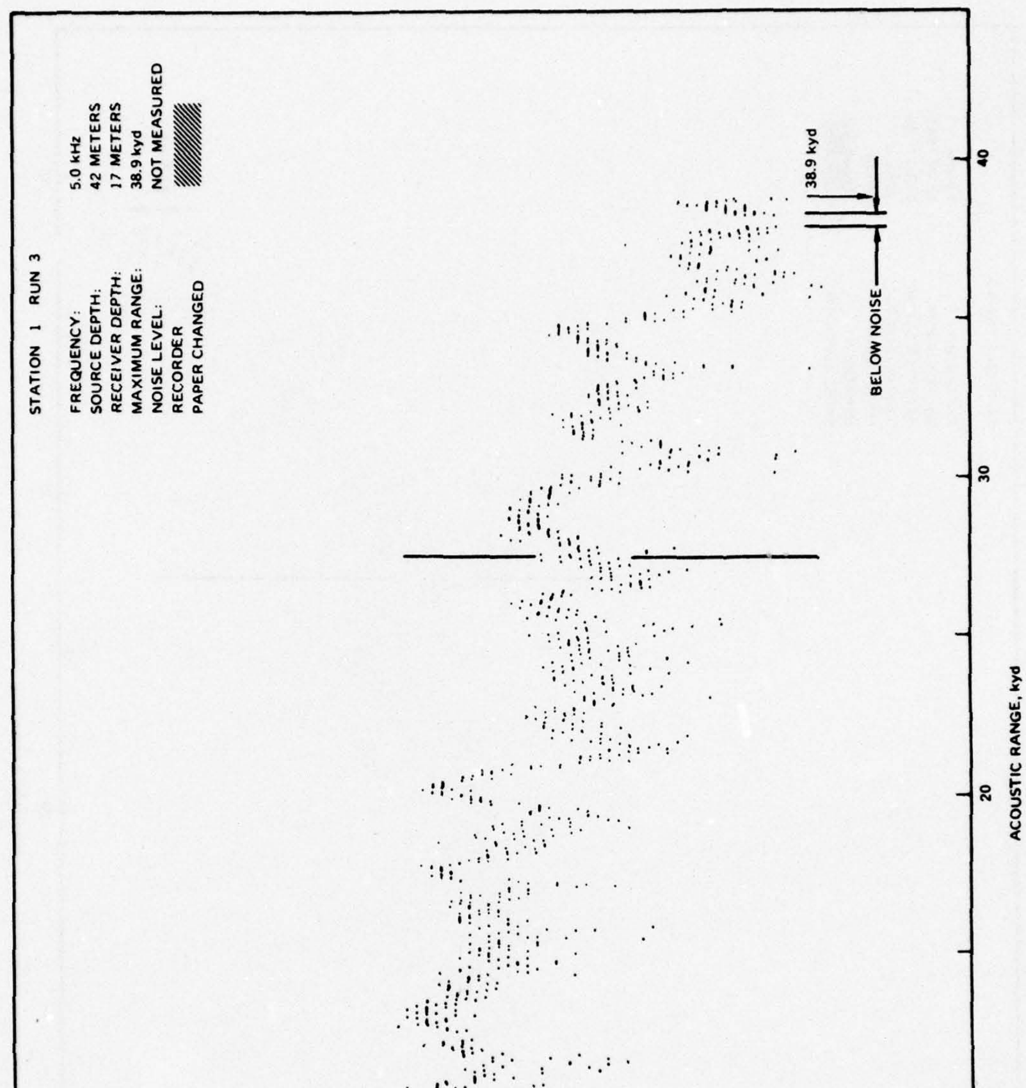

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 113 dB
RECORDER PAPER CHANGED
38.9 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

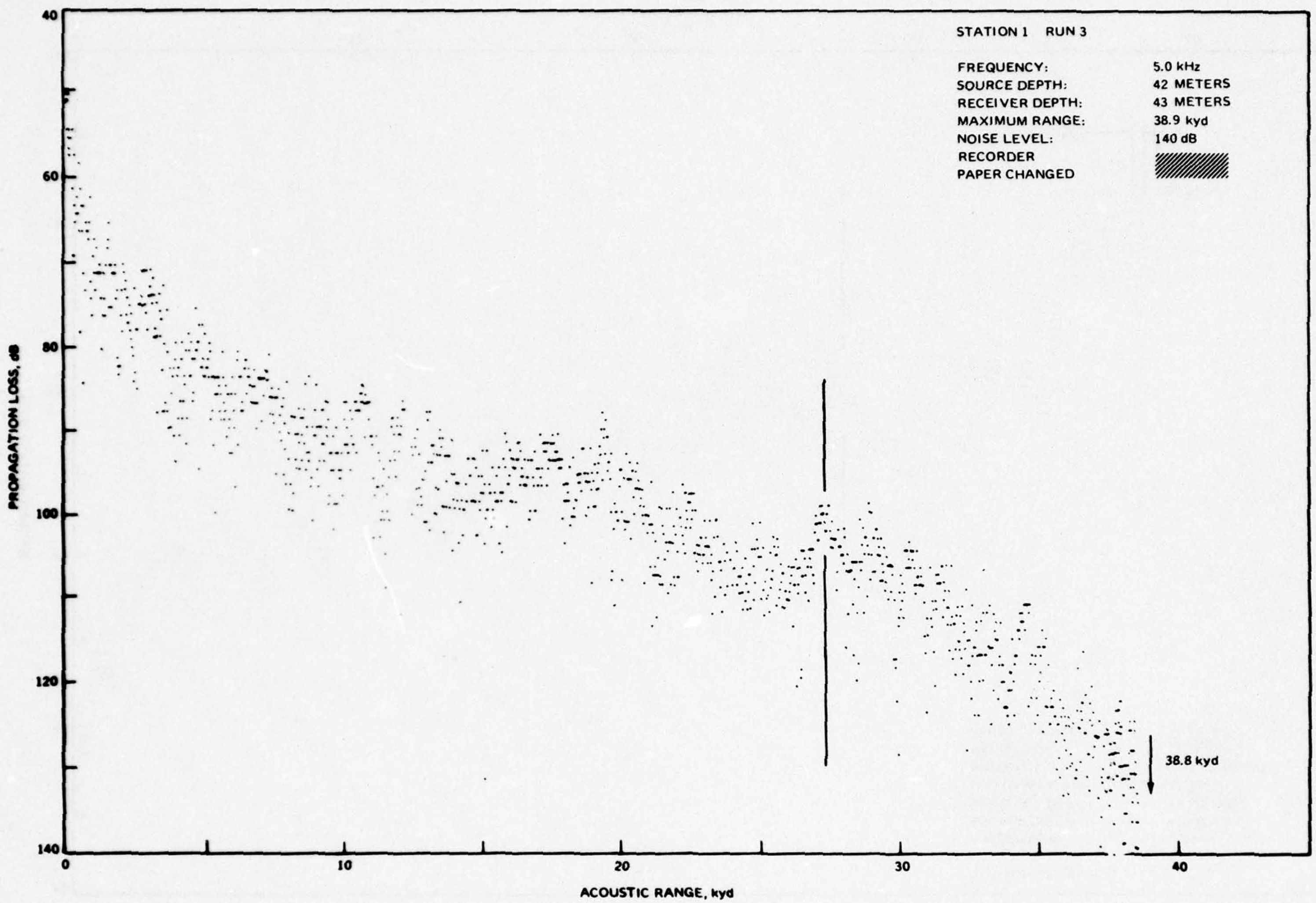


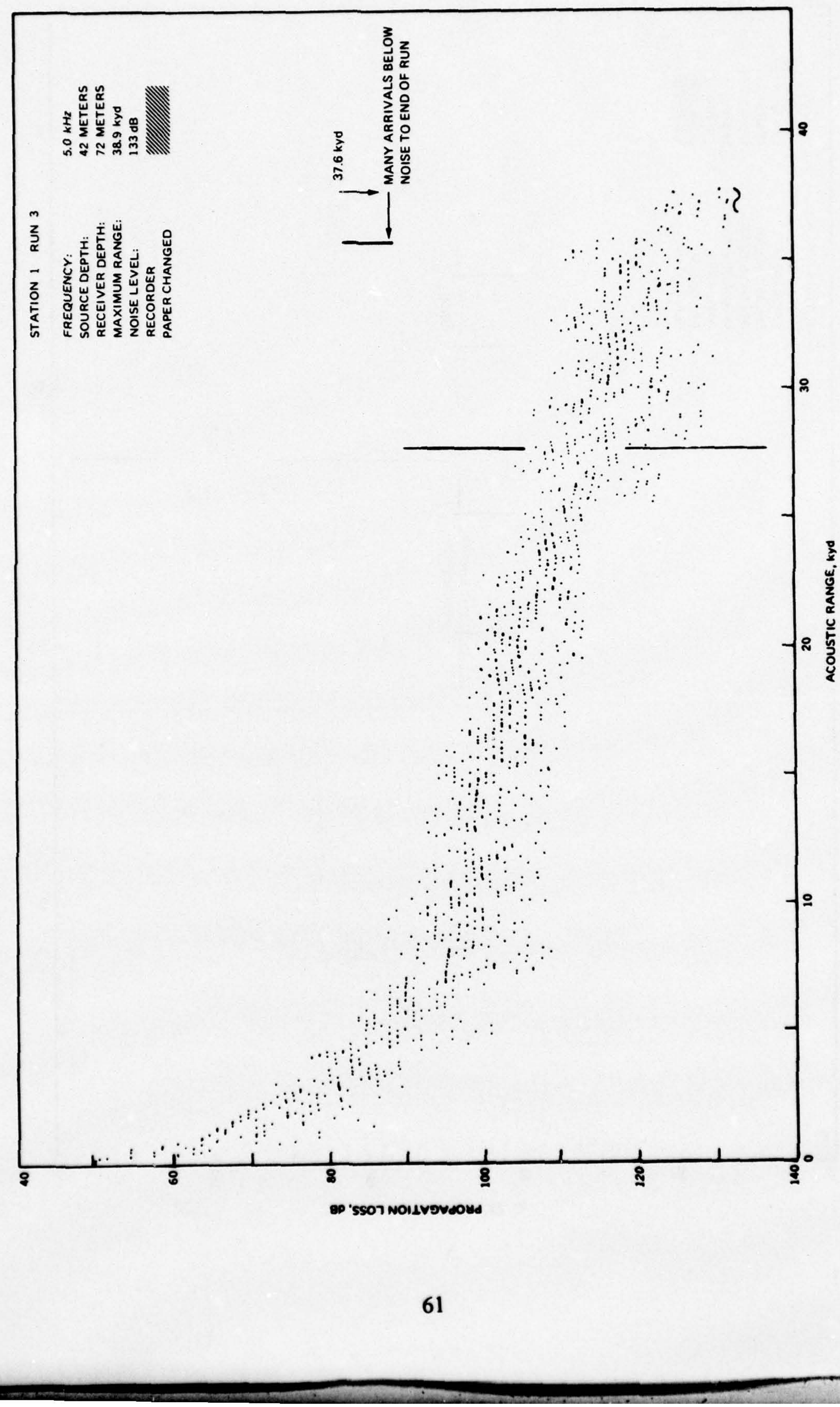
STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 101-116 dB
RECORDER PAPER CHANGED
38.2 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
MANY ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

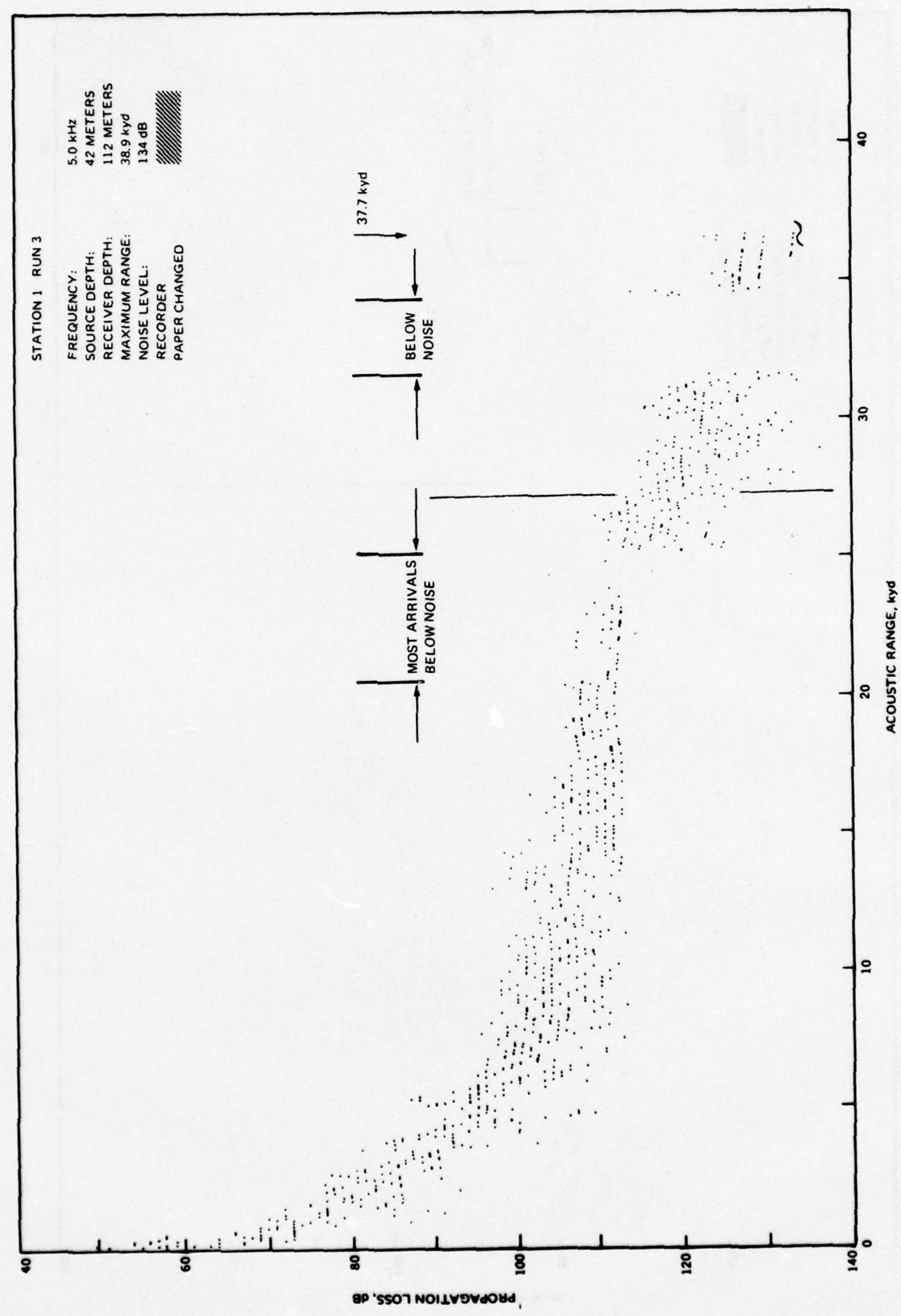

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 102-119 dB
RECORDER
PAPER CHANGED
SOURCE INOPERATIVE
MANY ARRIVALS
BELOW NOISE
38.0 kyd
MOST ARRIVALS
BELOW NOISE
TO END OF RUN
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40


STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER
PAPER CHANGED
38.9 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
PROPAGATION LOSS, dB


STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
38.9 kyd
BELOW NOISE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
60
80
100
120
140


STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 140 dB
RECORDER PAPER CHANGED
38.8 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 133 dB
RECORDER PAPER CHANGED
37.6 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

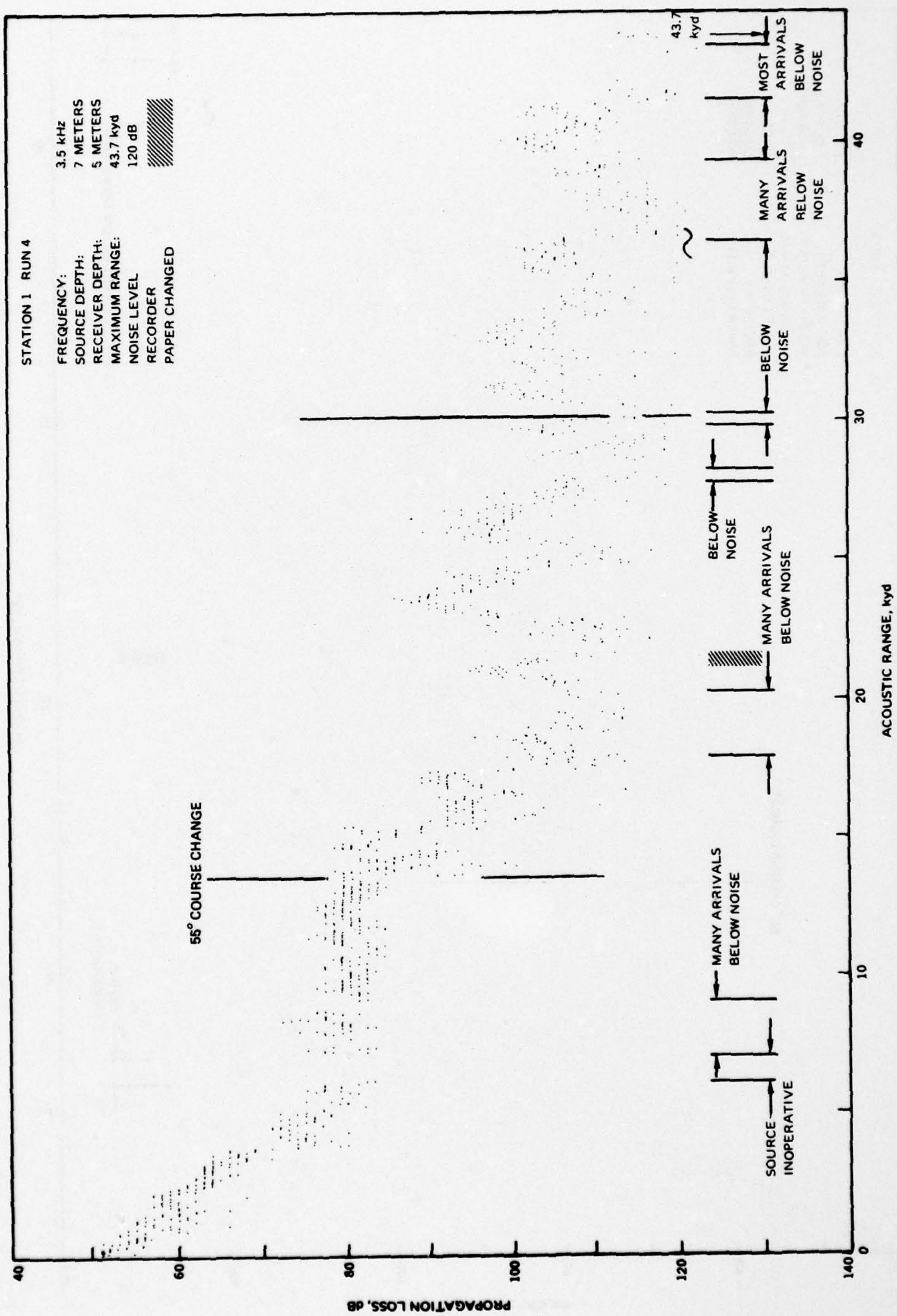


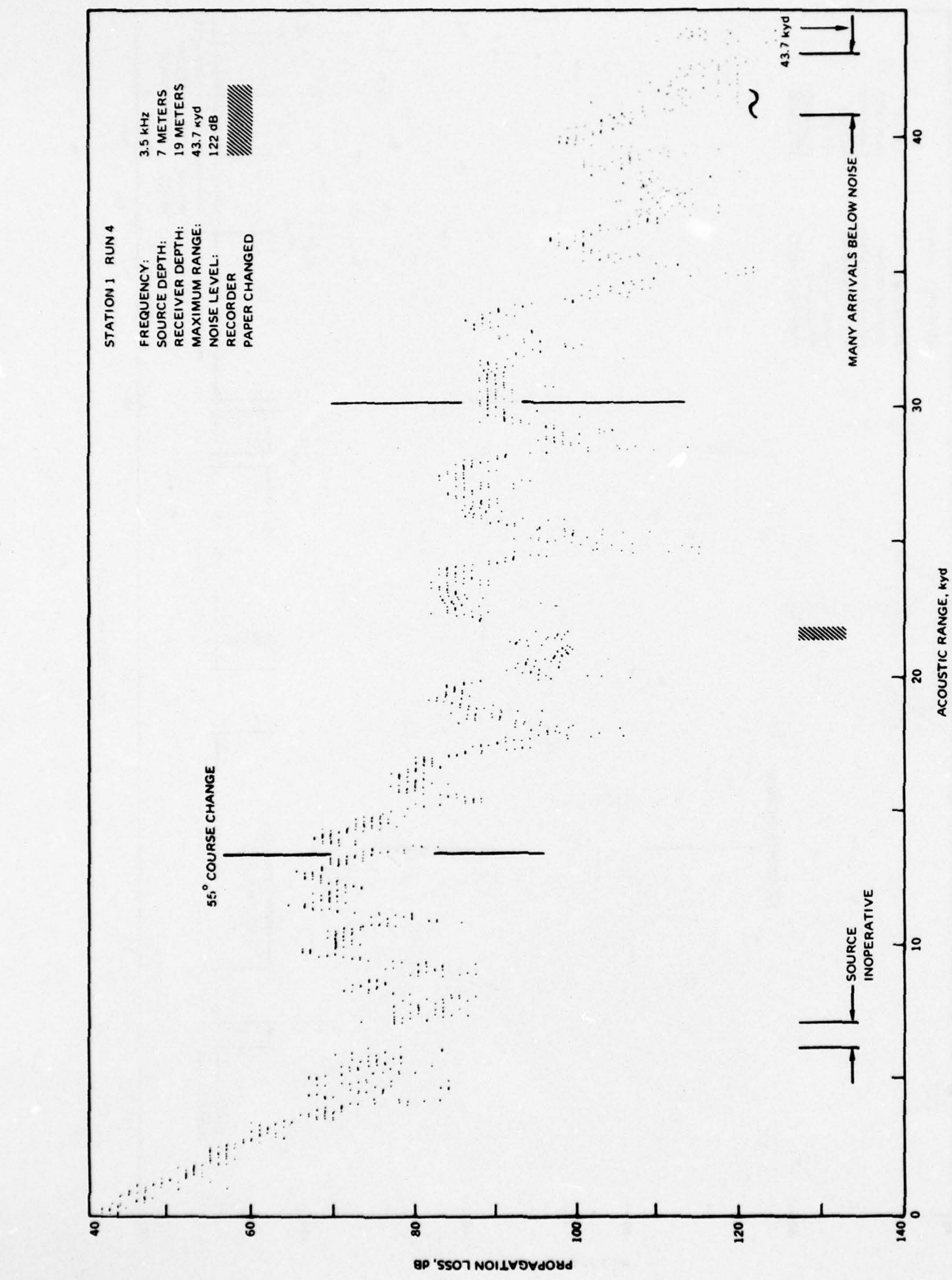
STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 134 dB
RECORDER PAPER CHANGED
37.7 kyd
BELOW NOISE
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

APPENDIX D

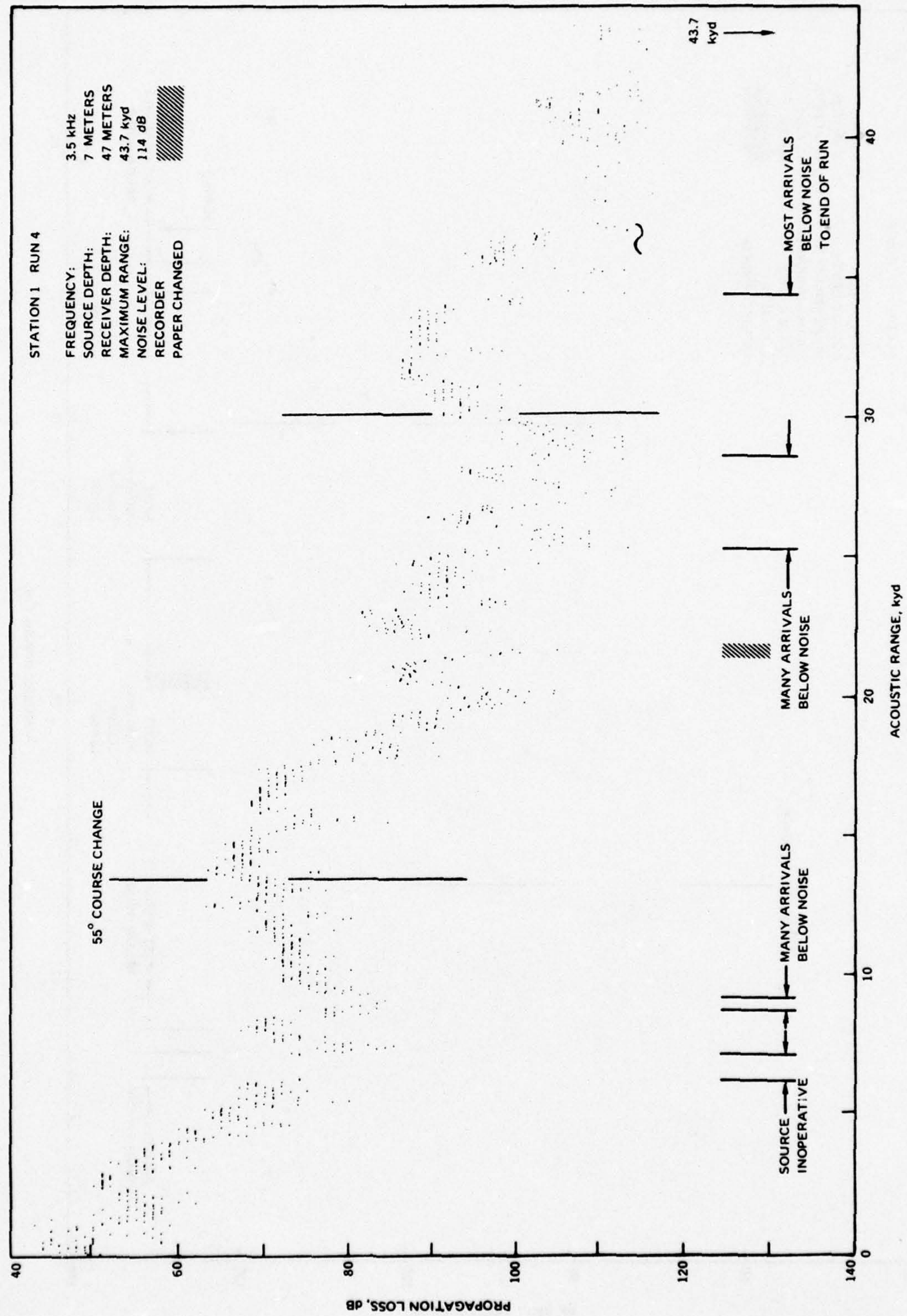
STATION 1 RUN 4

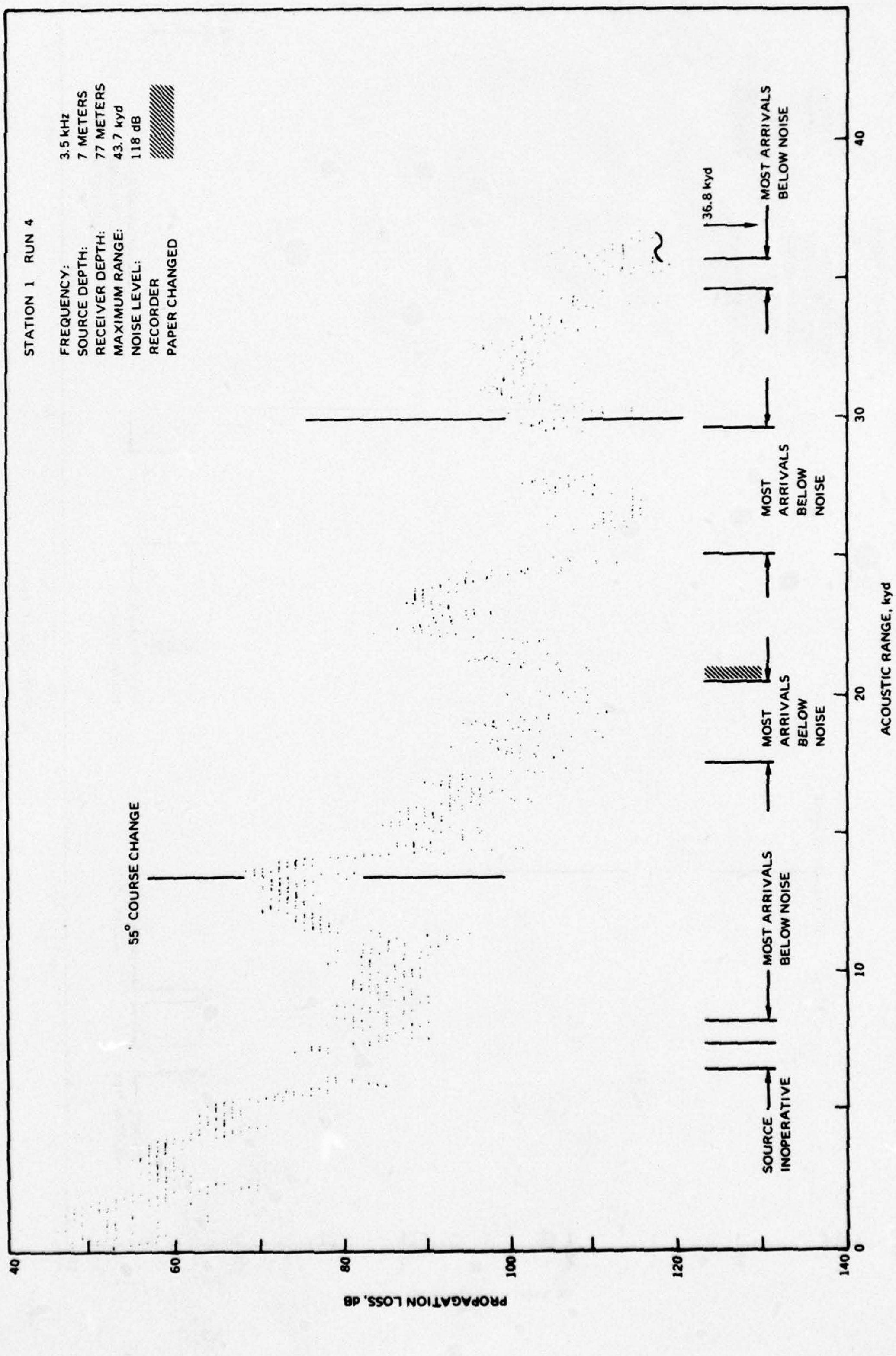
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

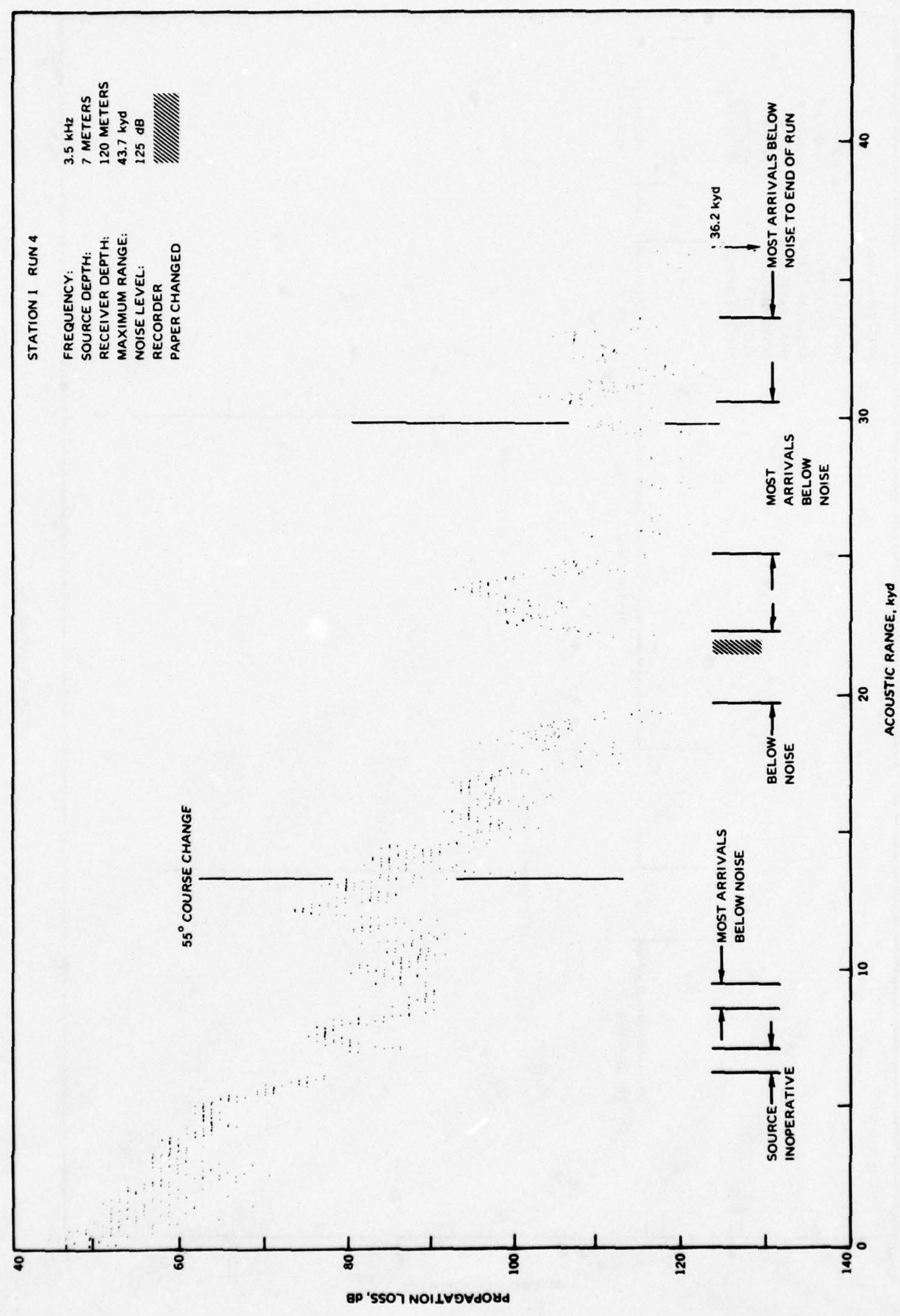

STATION 1 RUN 4
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 7 METERS
RECEIVER DEPTH: 5 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL 120 dB
RECORDER PAPER CHANGED
55° COURSE CHANGE
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE
BELOW NOISE
BELOW NOISE
MANY ARRIVALS RELOW NOISE
MOST ARRIVALS BELOW NOISE
43.7 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

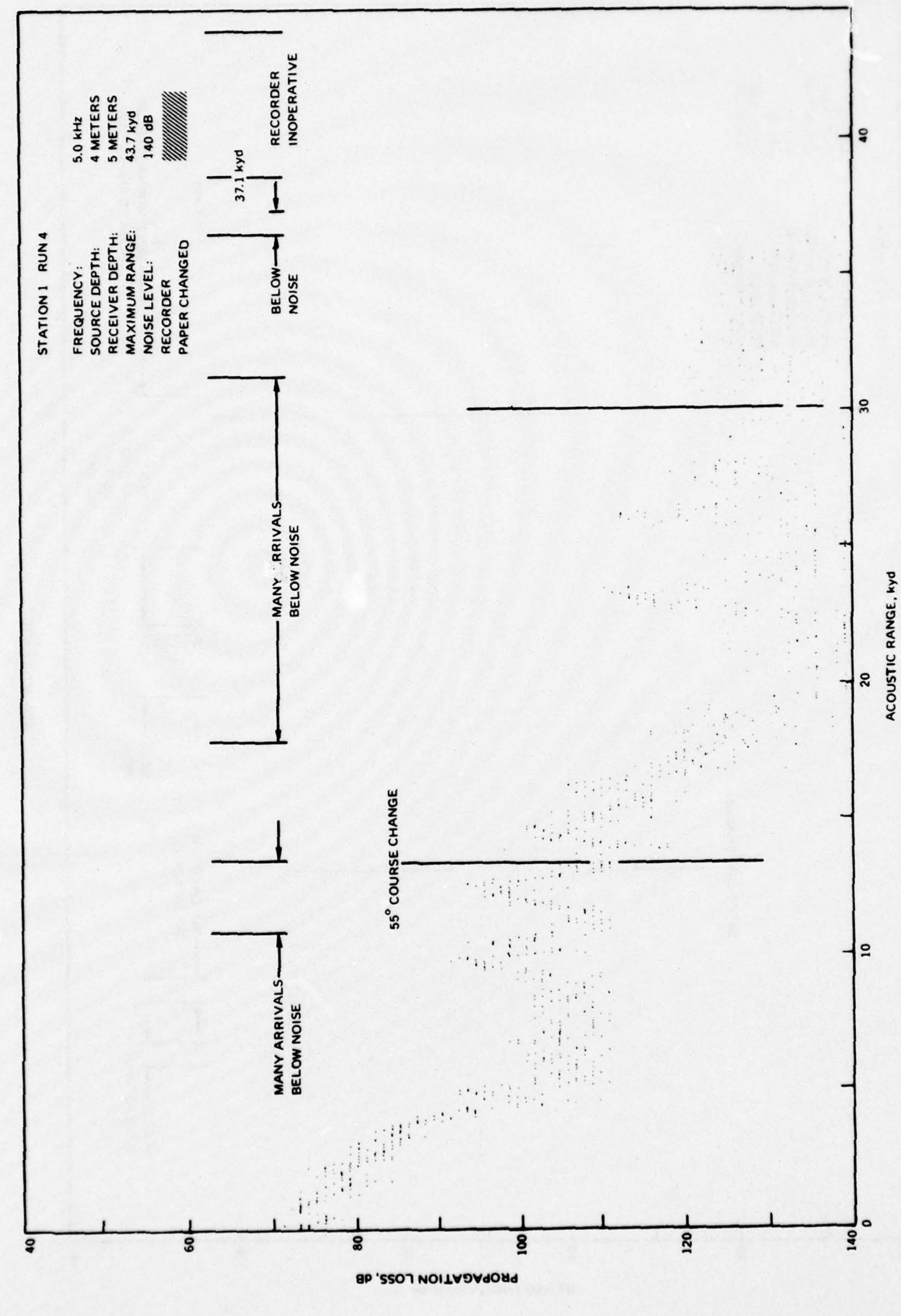


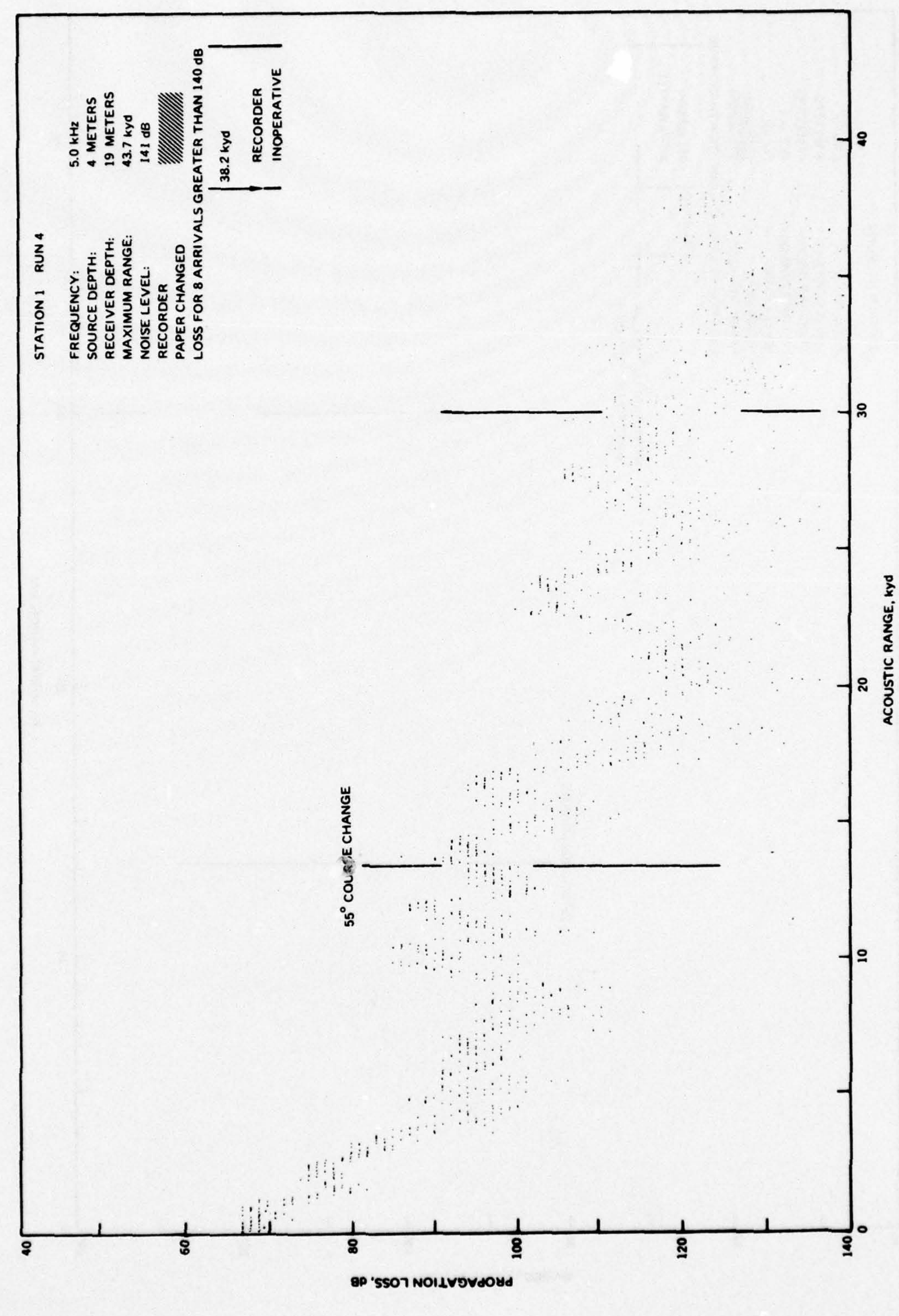
STATION 1 RUN 4
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 7 METERS
RECEIVER DEPTH: 19 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 122 dB
RECORDER PAPER CHANGED
55° COURSE CHANGE
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
43.7 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

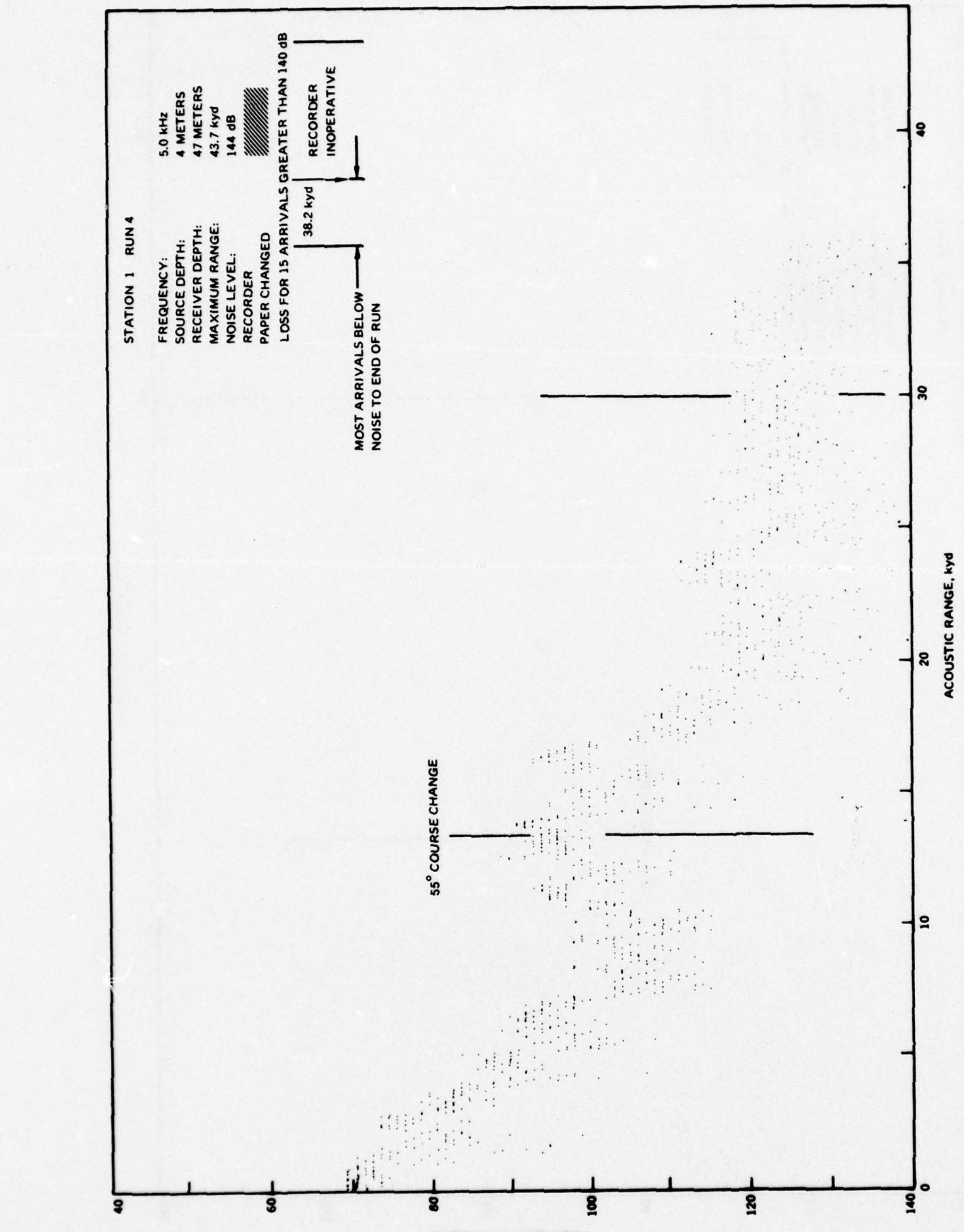

STATION 1 RUN 4
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 7 METERS
RECEIVER DEPTH: 47 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 114 dB
RECORDER PAPER CHANGED
55° COURSE CHANGE
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
43.7 kyd
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
40
60
80
100
120
140


STATION 1 RUN 4
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 7 METERS
RECEIVER DEPTH: 77 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 118 dB
RECORDER PAPER CHANGED
55° COURSE CHANGE
SOURCE INOPERATIVE
MOST ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
36.8 kyd
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

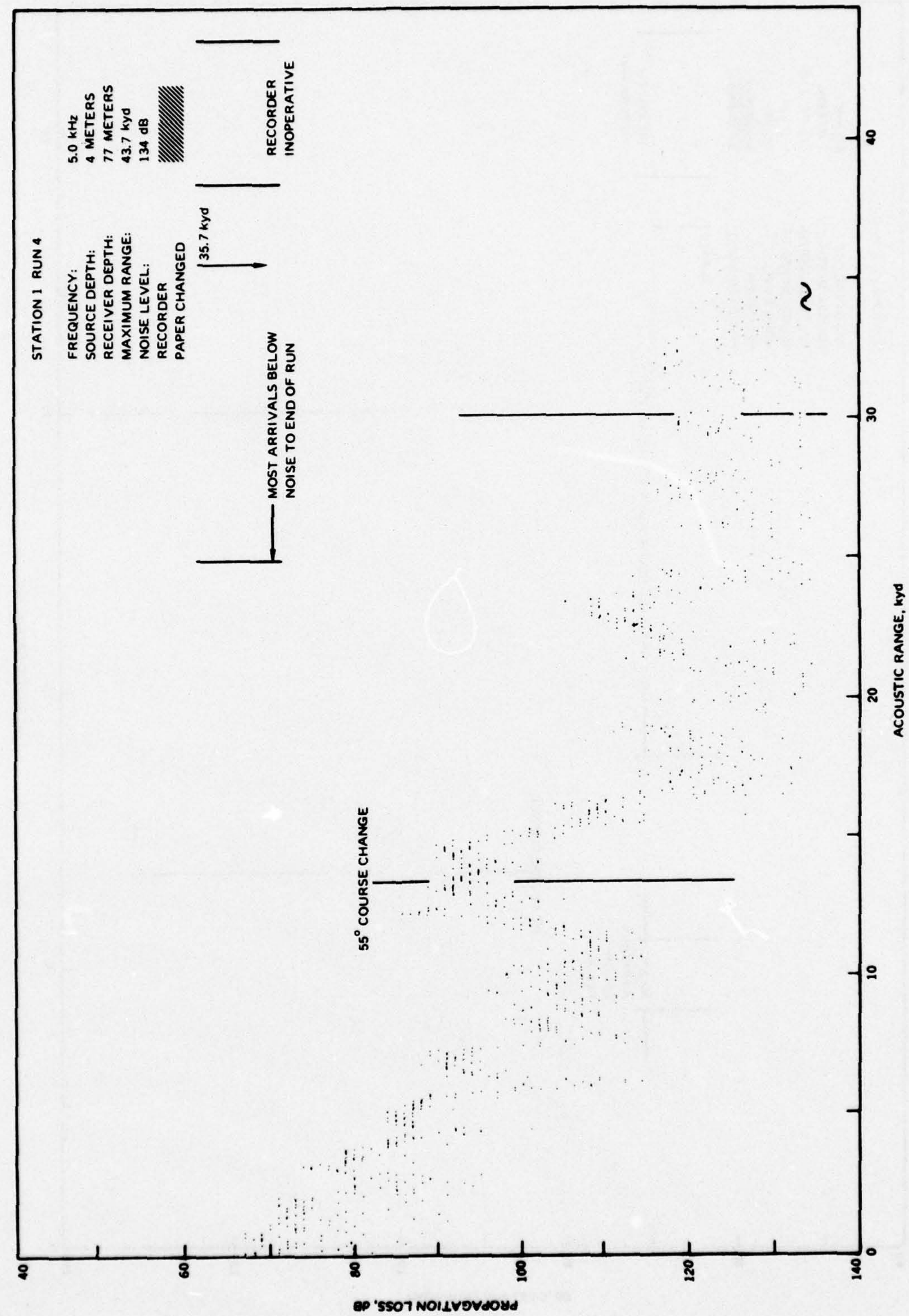

STATION I RUN 4
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 7 METERS
RECEIVER DEPTH: 120 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 125 dB
RECORDER PAPER CHANGED
55° COURSE CHANGE
SOURCE INOPERATIVE
MOST ARRIVALS BELOW NOISE
BELOW NOISE
MOST ARRIVALS BELOW NOISE
36.2 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

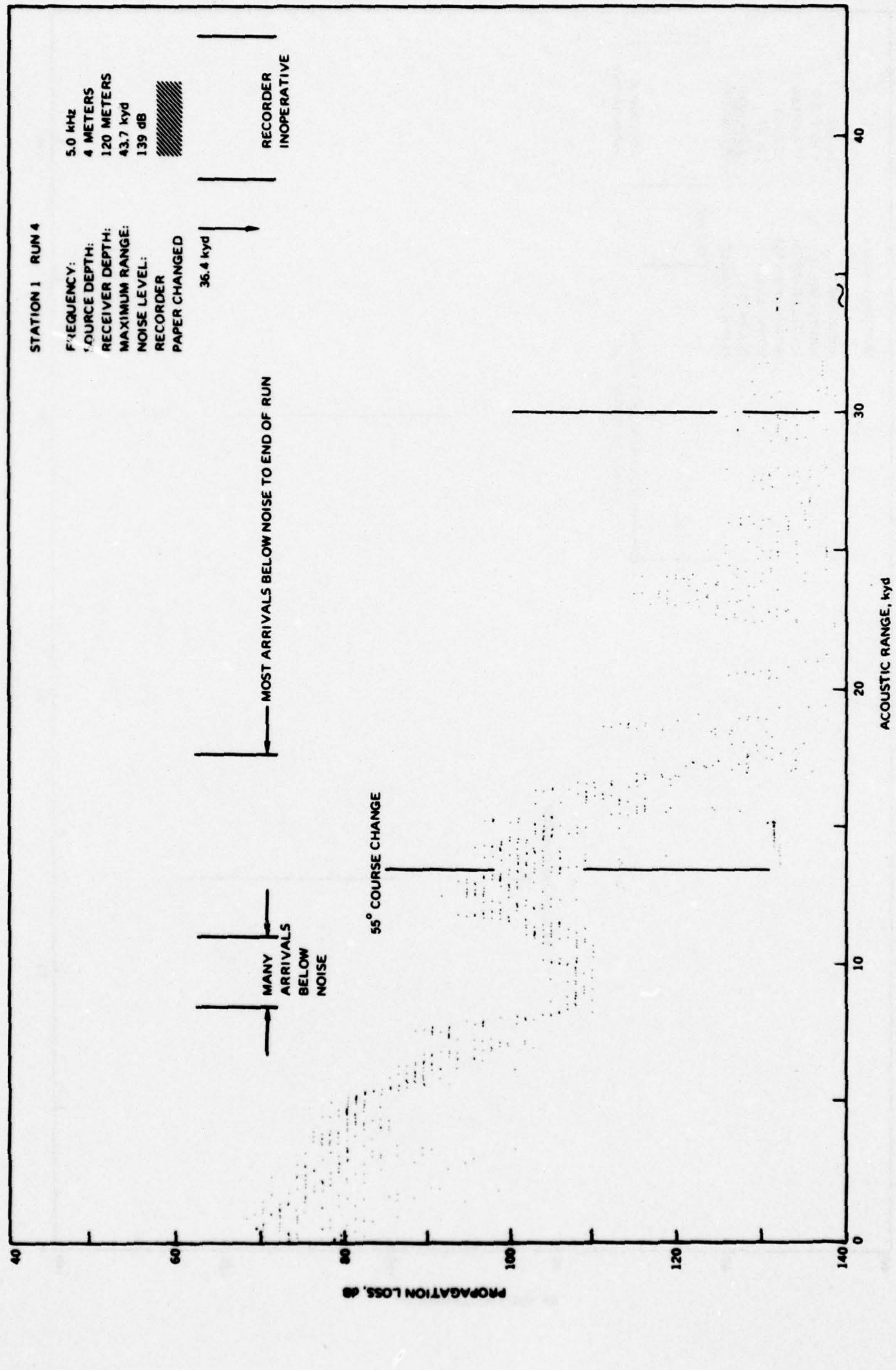

STATION 1 RUN 4
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 4 METERS
RECEIVER DEPTH: 5 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 140 dB
RECORDER PAPER CHANGED
MANY ARRIVALS BELOW NOISE
55° COURSE CHANGE
MANY ARRIVALS BELOW NOISE
BELOW NOISE
37.1 kyd
RECORDER INOPERATIVE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd


STATION 1 RUN 4
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 4 METERS
RECEIVER DEPTH: 19 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 141 dB
RECORDER PAPER CHANGED
LOSS FOR 8 ARRIVALS GREATER THAN 140 dB
38.2 kyd
RECORDER INOPERATIVE
55° COURSE CHANGE
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB



STATION 1 RUN 4
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 4 METERS
RECEIVER DEPTH: 47 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 144 dB
RECORDER PAPER CHANGED
LOSS FOR 15 ARRIVALS GREATER THAN 140 dB
38.2 kyd
RECORDER INOPERATIVE
MOST ARRIVALS BELOW NOISE TO END OF RUN
55° COURSE CHANGE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

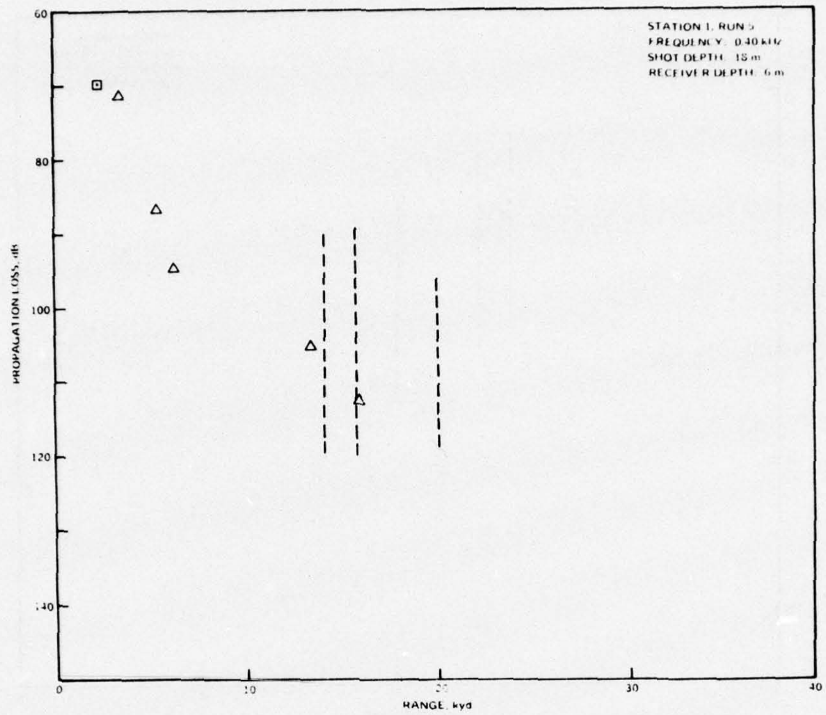

STATION 1 RUN 4
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 4 METERS
RECEIVER DEPTH: 77 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 134 dB
RECORDER PAPER CHANGED
35.7 kyd
RECORDER INOPERATIVE
MOST ARRIVALS BELOW NOISE TO END OF RUN
55° COURSE CHANGE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

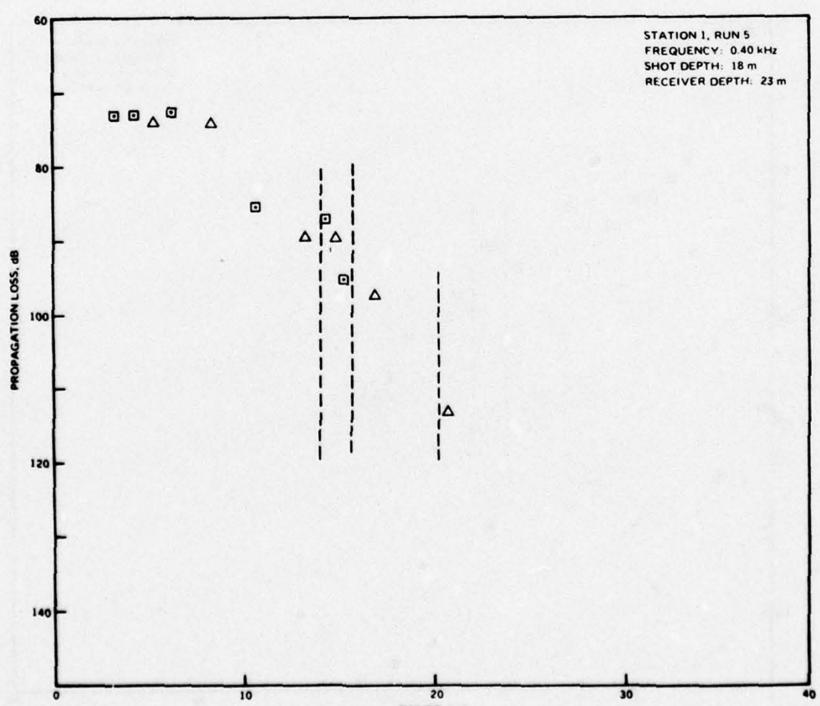

STATION 1 RUN 4
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 4 METERS
RECEIVER DEPTH: 120 METERS
MAXIMUM RANGE: 43.7 kyd
NOISE LEVEL: 139 dB
RECORDER PAPER CHANGED
36.4 kyd
RECORDER INOPERATIVE
MOST ARRIVALS BELOW NOISE TO END OF RUN
55° COURSE CHANGE
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

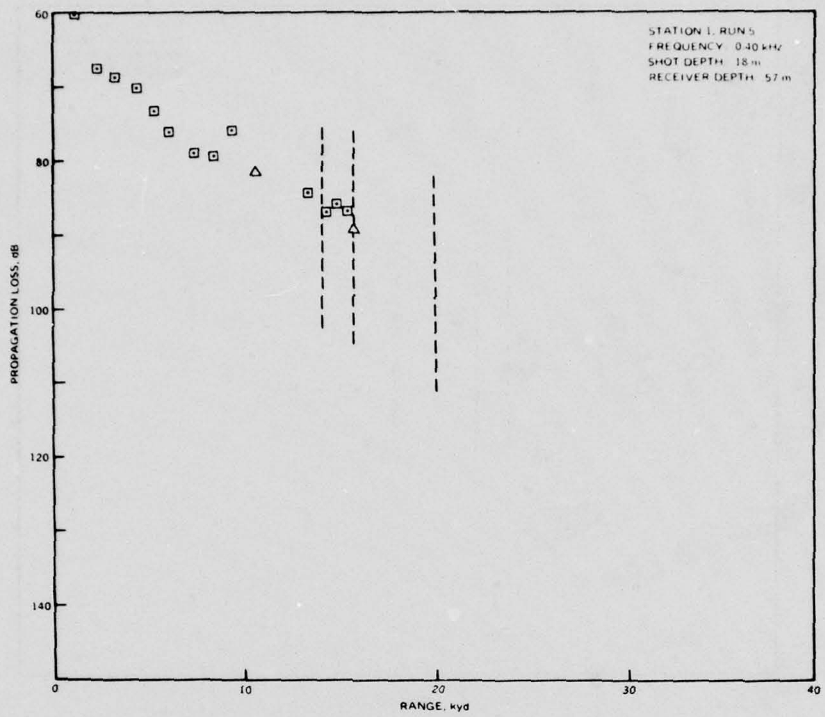
APPENDIX E

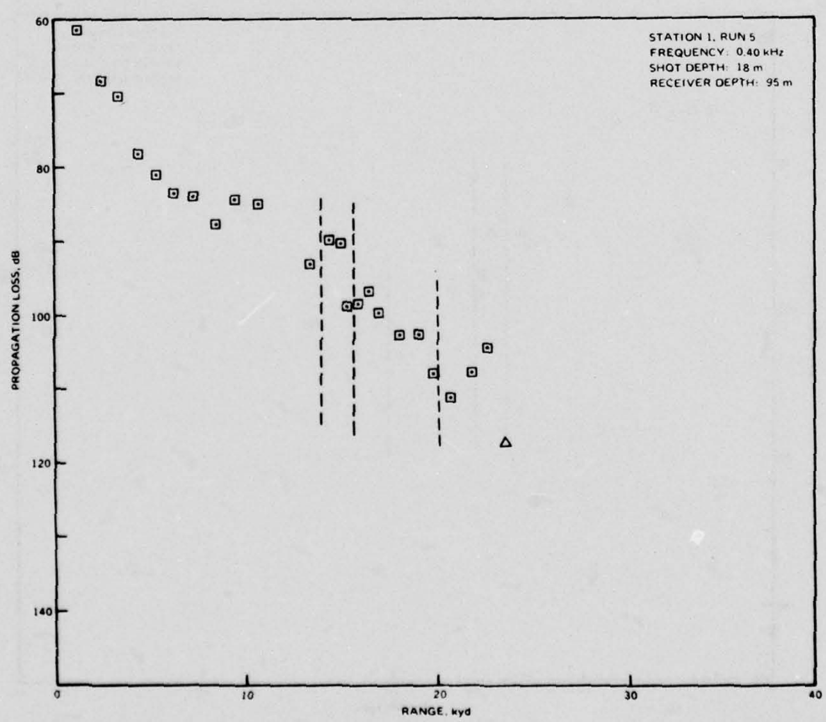
STATION 1 RUN 5

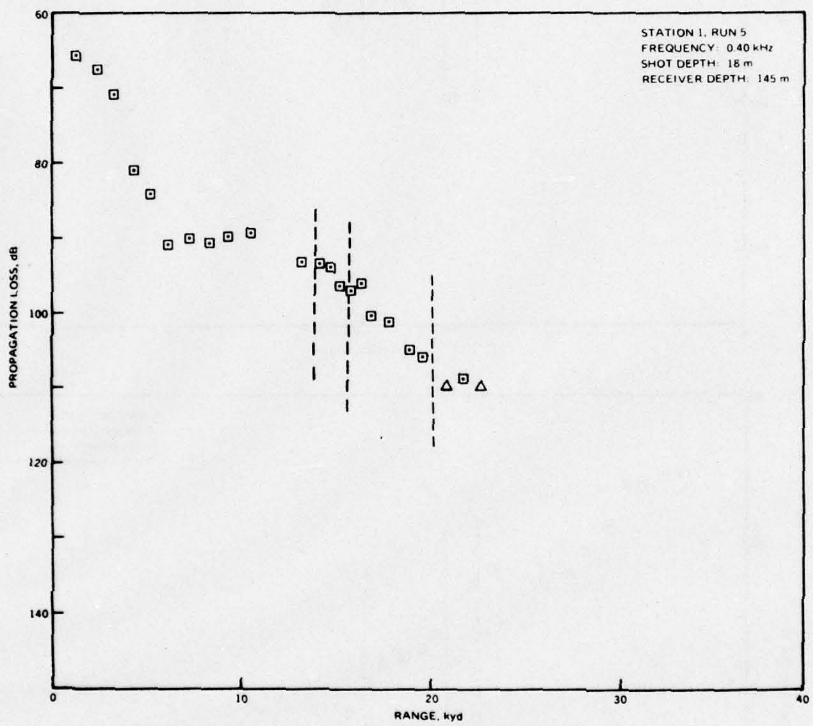
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

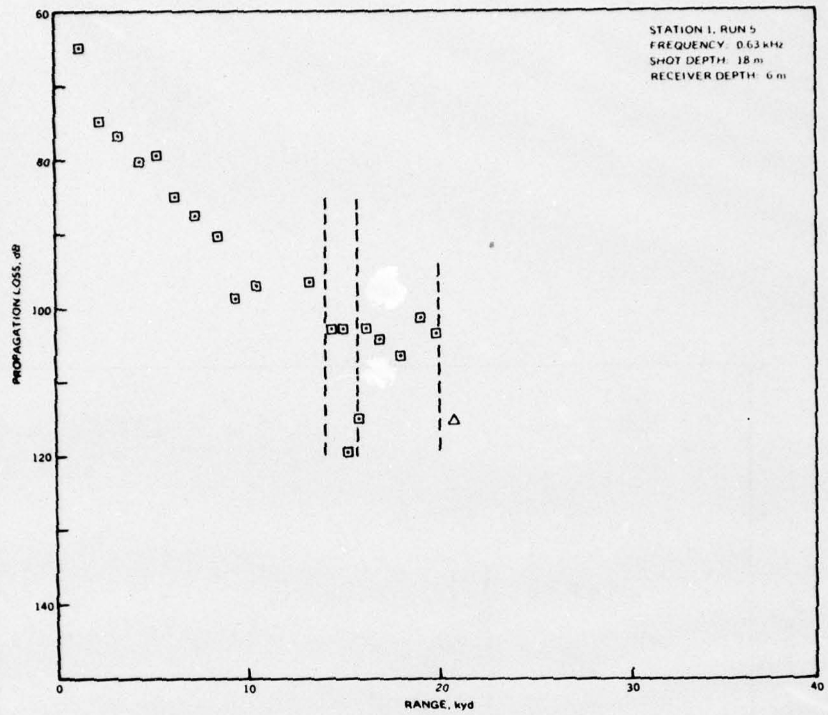

STATION 1, RUN 5
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION 1, RUN 5
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd

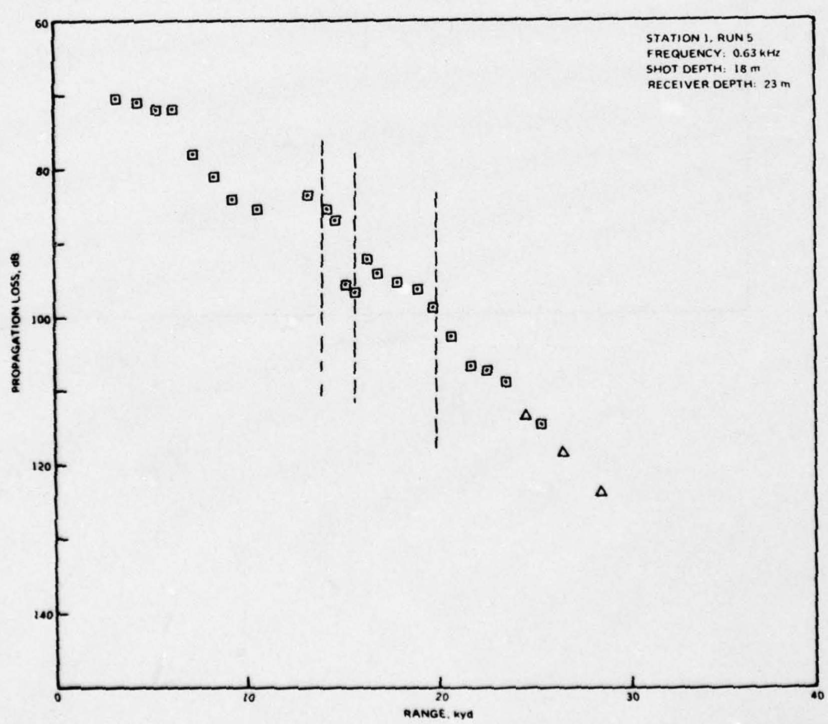

STATION 1, RUN 5
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION 1, RUN 5
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 95 m
PROPAGATION LOSS, dB
RANGE, kyd

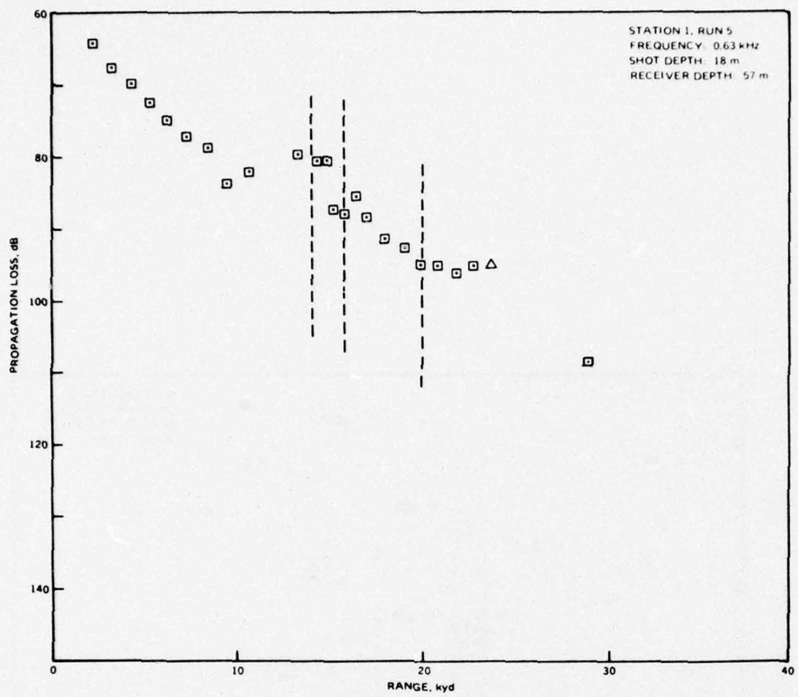

STATION 1, RUN 5
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40

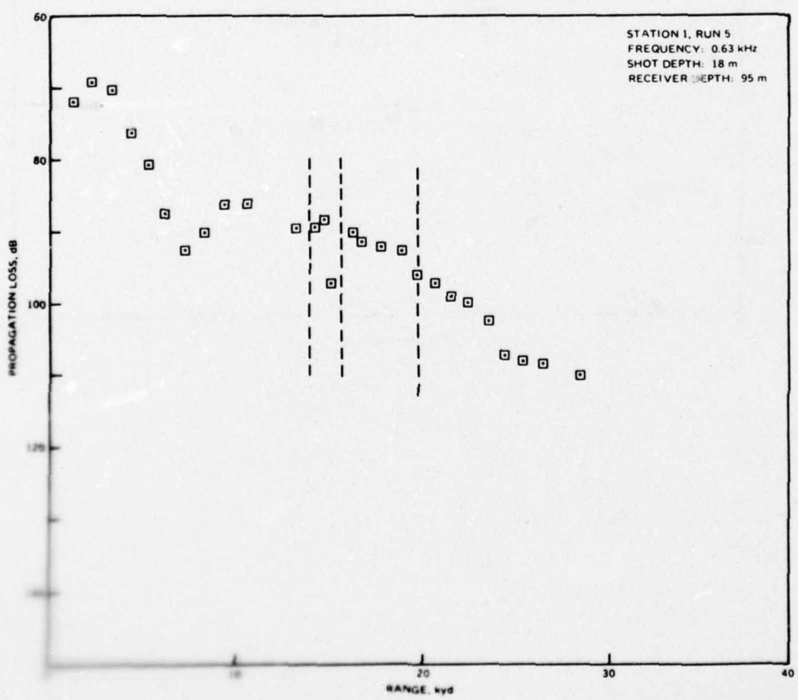


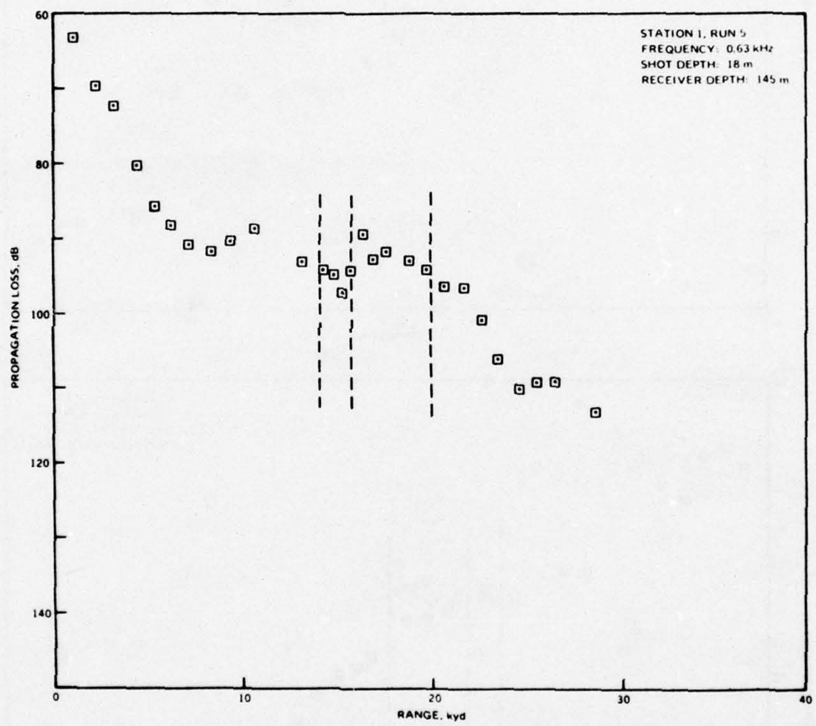
STATION 1, RUN 5
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd

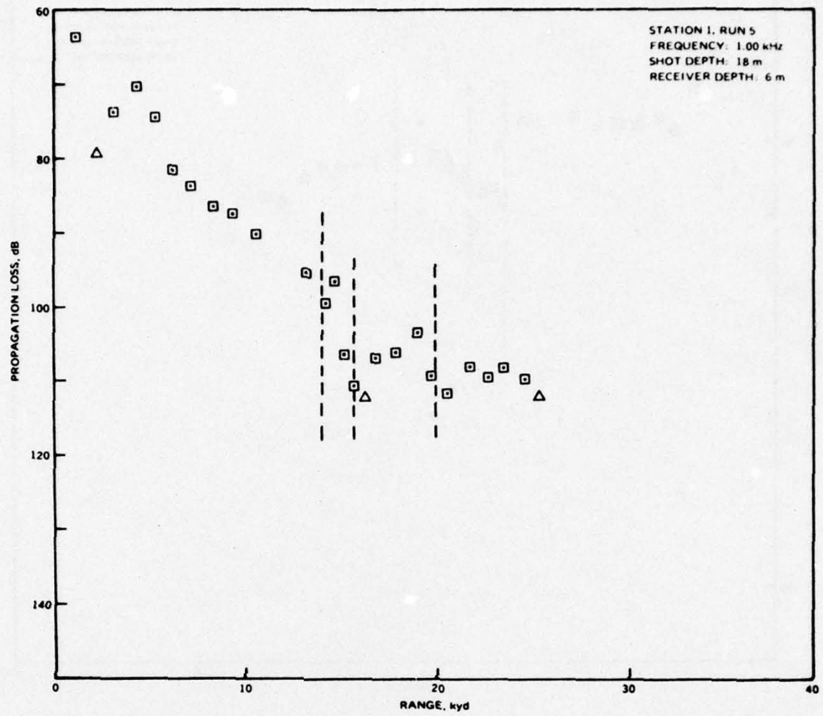


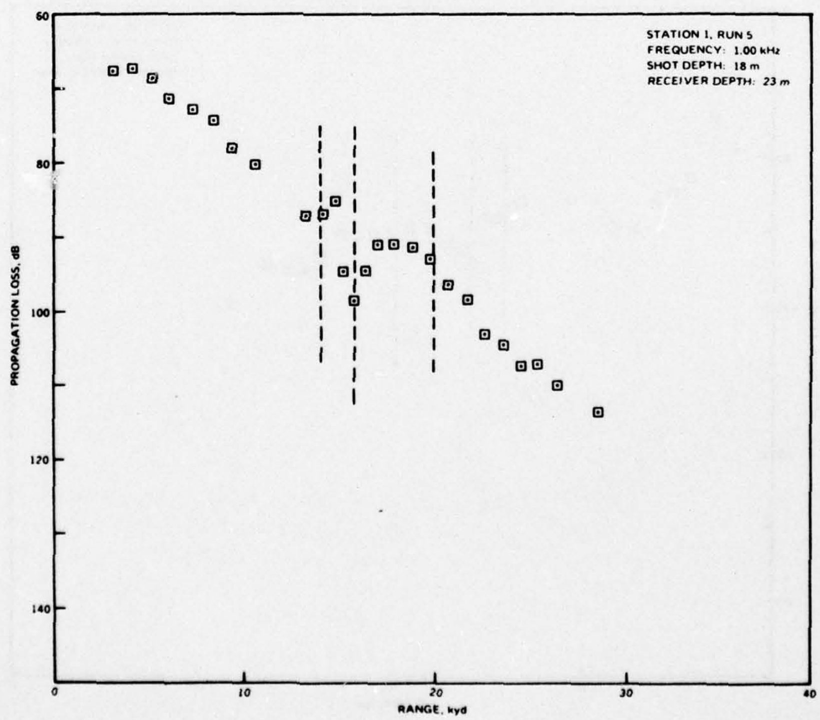
STATION 1, RUN 5
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd

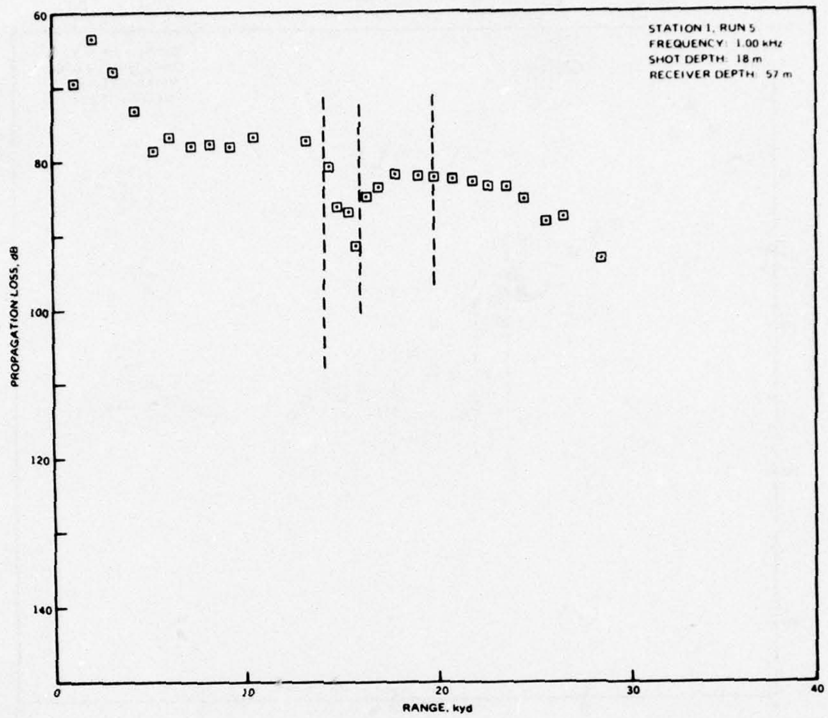

STATION 1, RUN 5
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

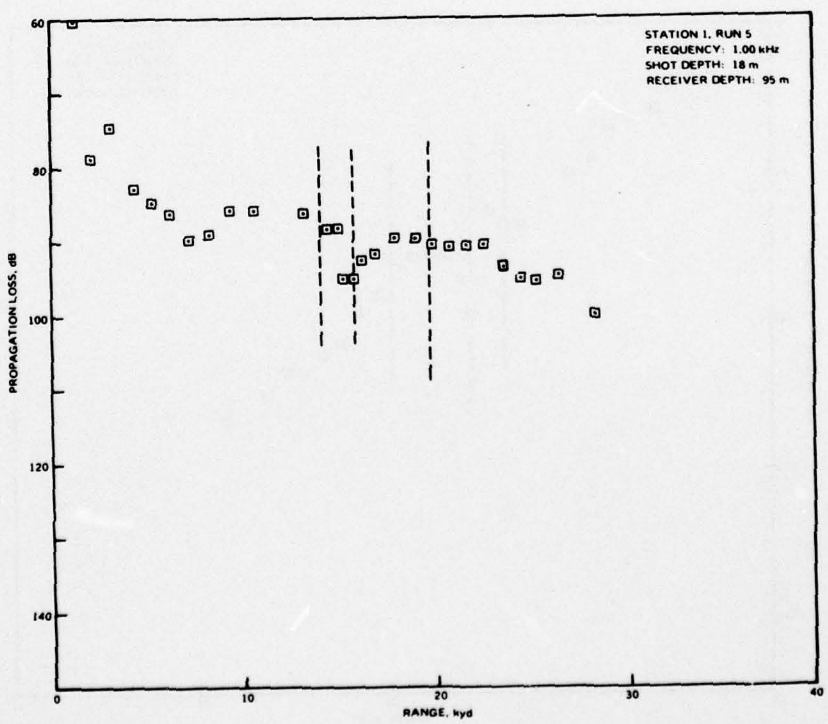

STATION 1, RUN 5
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
PROPAGATION LOSS, dB
60
80
100
20
30
40

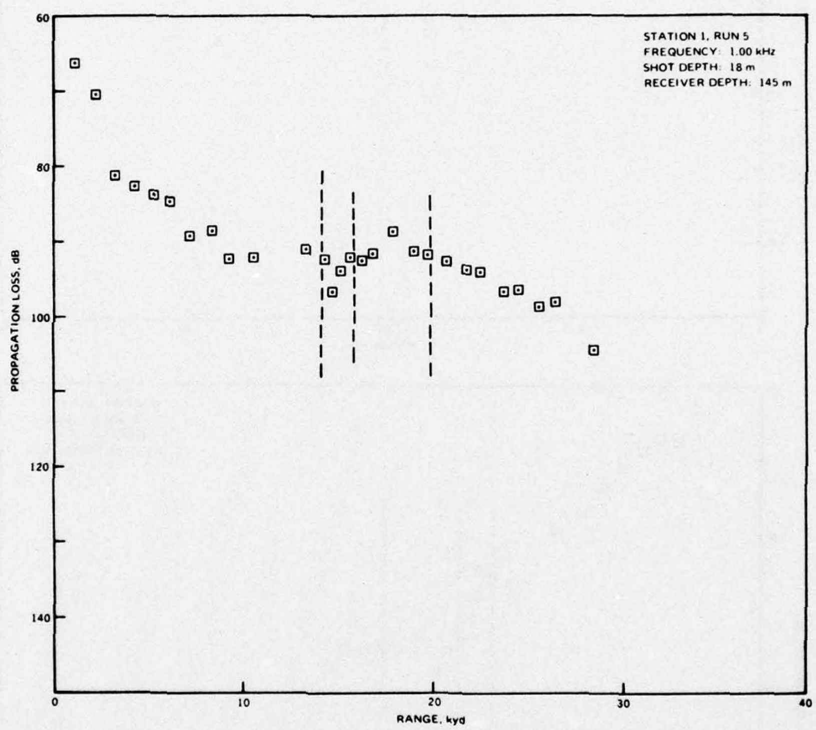

STATION 1, RUN 5
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
60
80
100
120
140
PROPAGATION LOSS, dB
0
10
20
30
40
RANGE, kyd

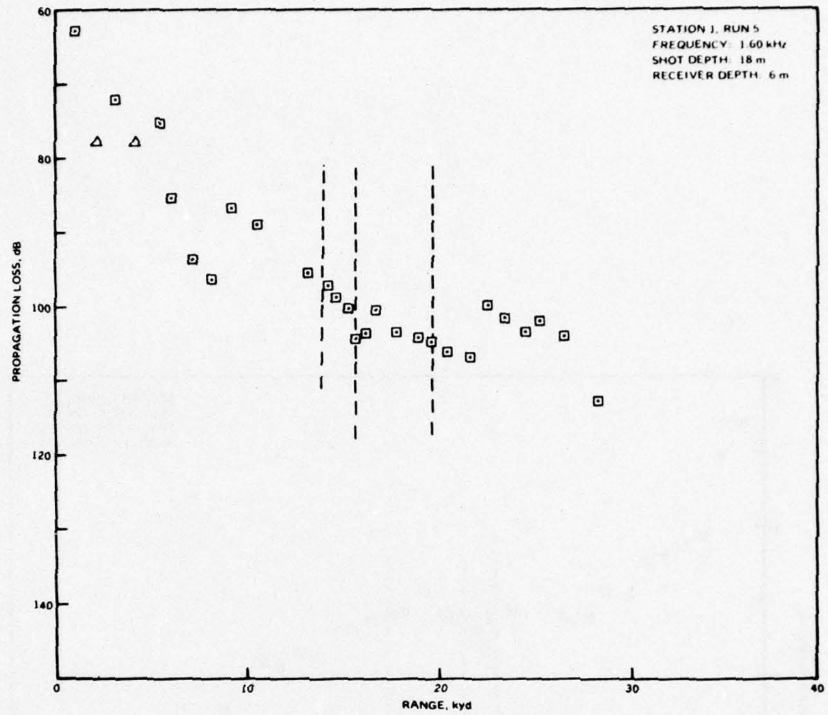

STATION 1, RUN 5
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd

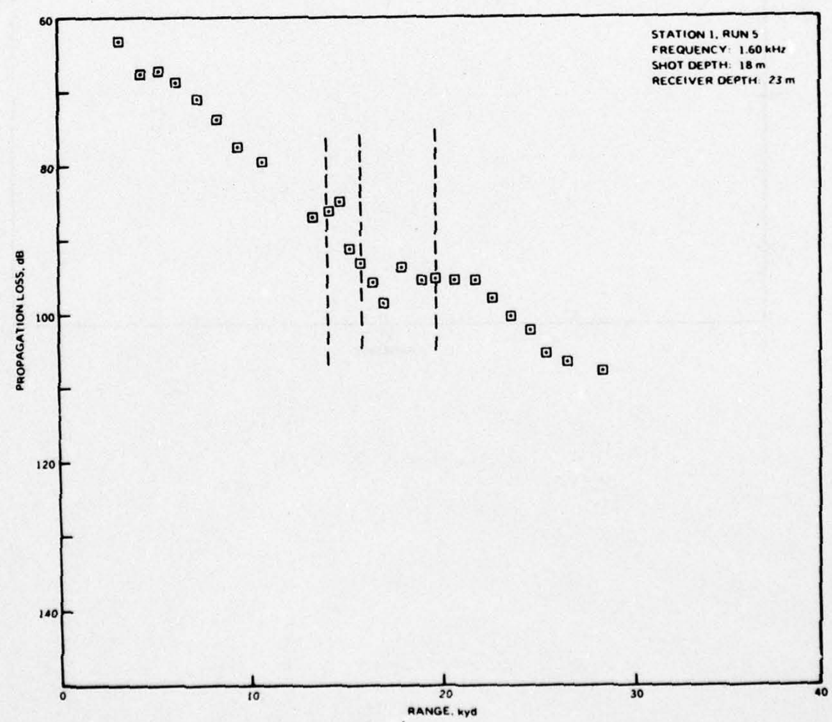

STATION 1, RUN 5
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd

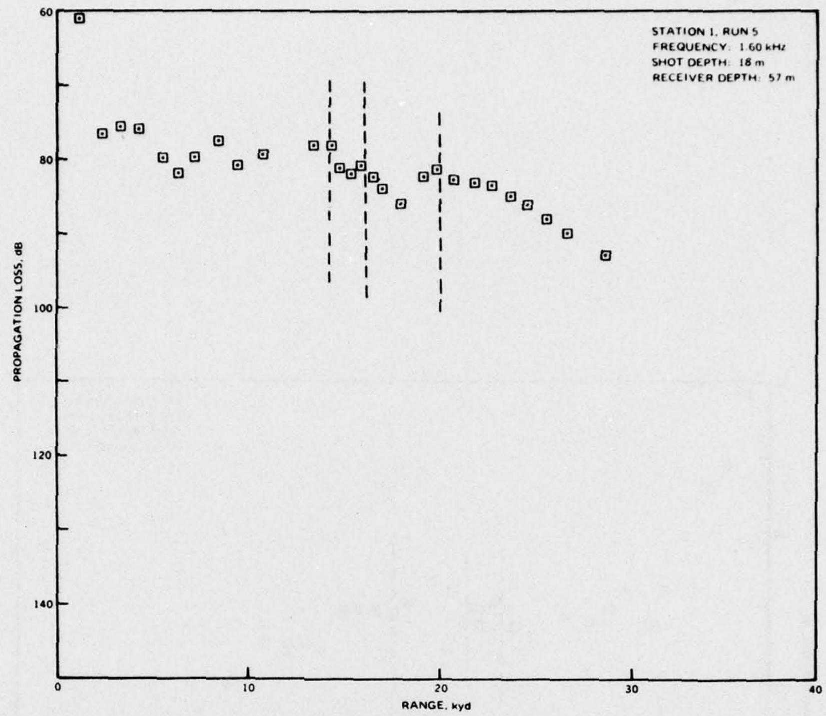

STATION 1, RUN 5
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

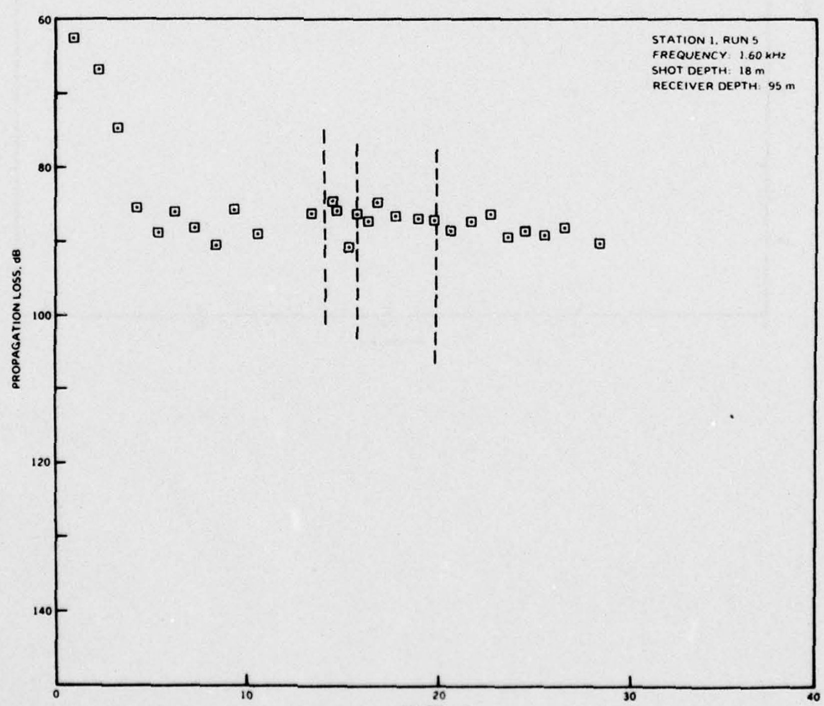

STATION 1, RUN 5
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 95 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

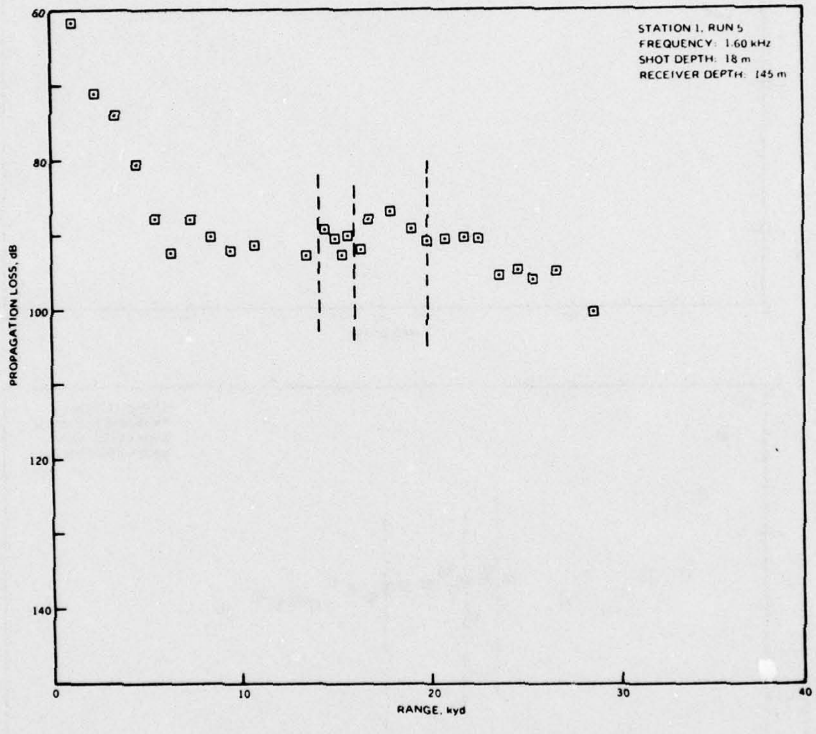

STATION 1, RUN 5
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

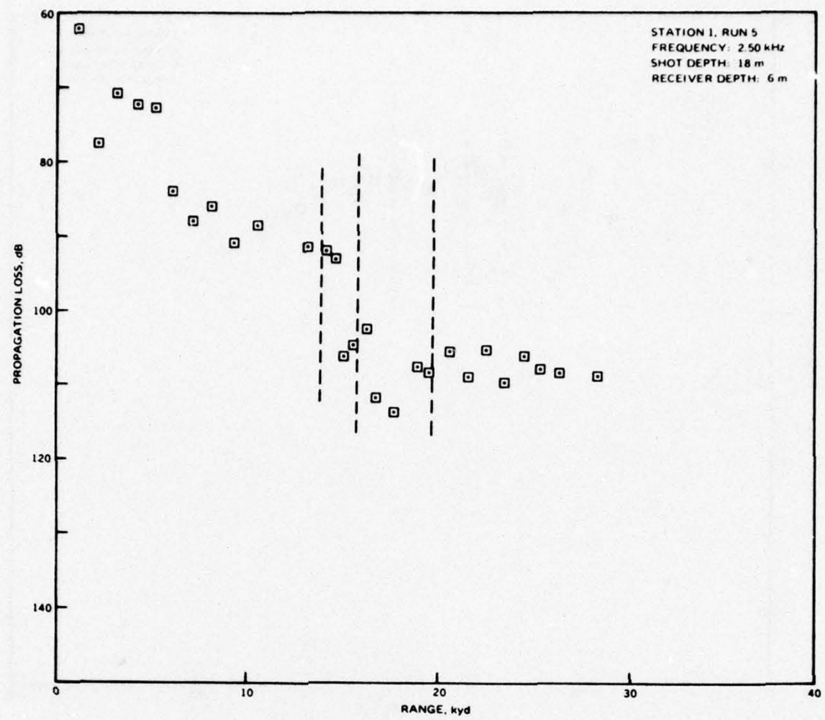

STATION J, RUN 5
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd

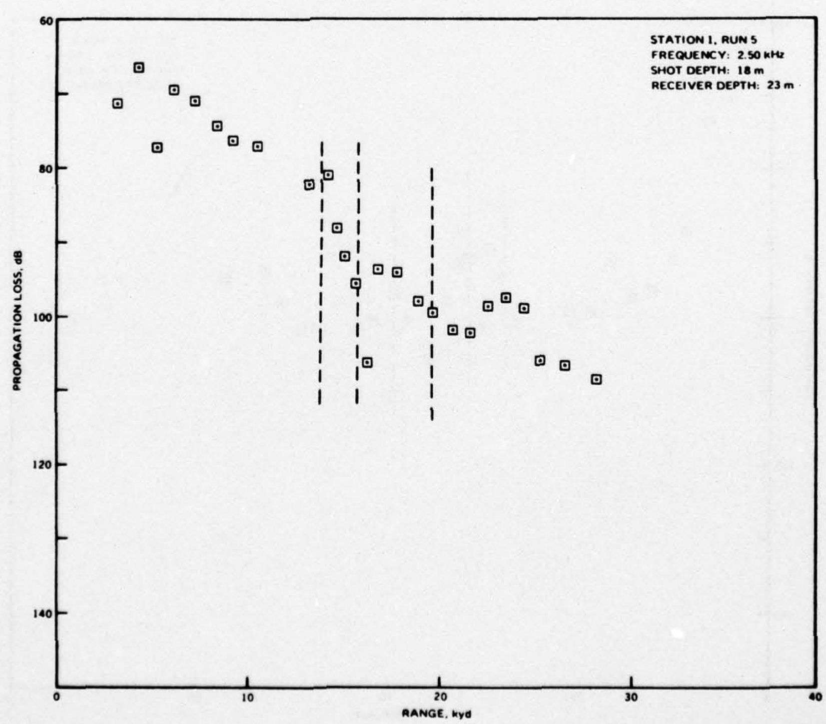

STATION J, RUN 5
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd

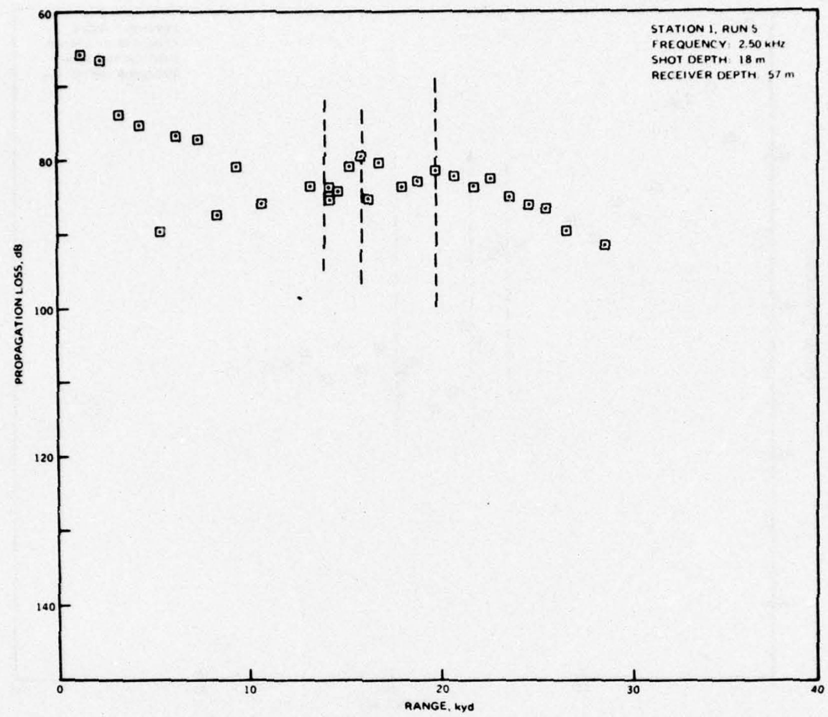

STATION 1, RUN 5
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
RANGE, kyd

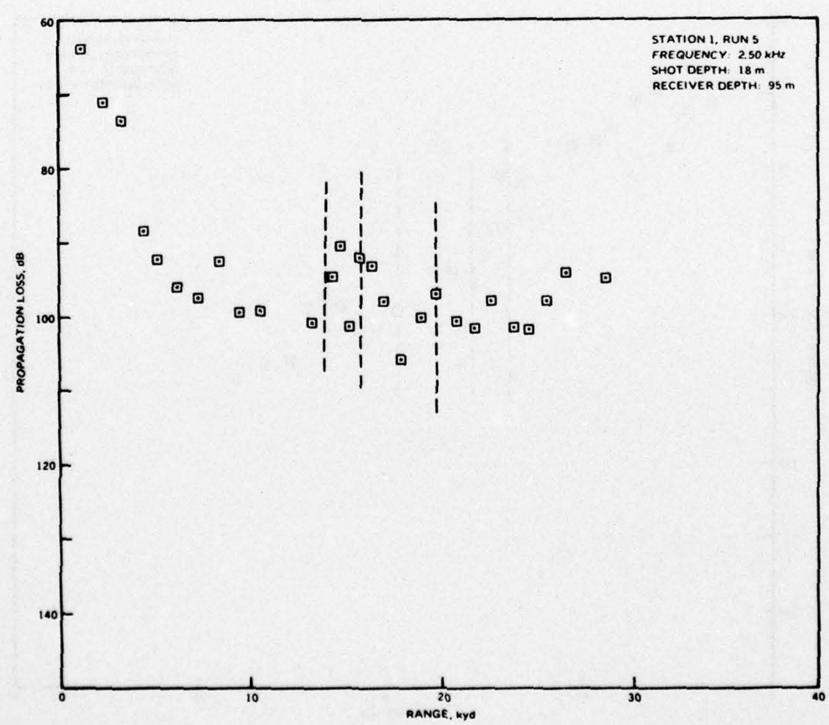

STATION 1, RUN 5
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 95 m
PROPAGATION LOSS, dB
RANGE, kyd

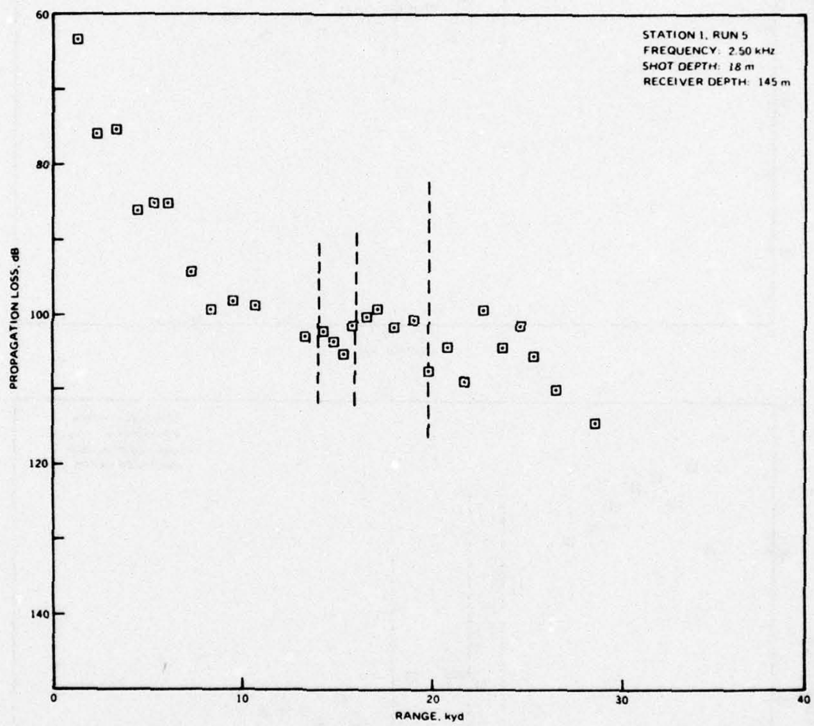

STATION 1, RUN 5
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40


STATION 1, RUN 5
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

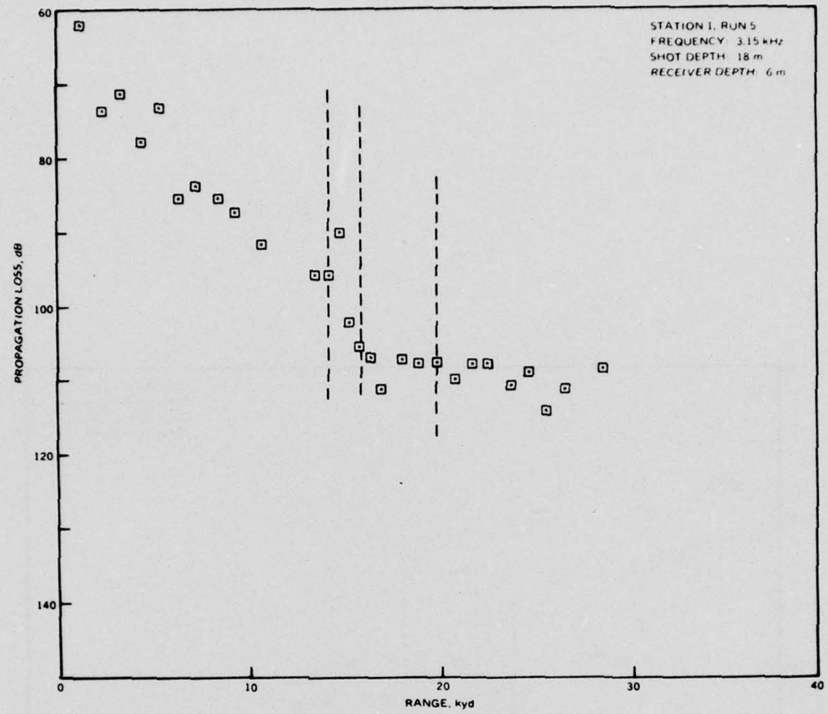

STATION 1, RUN 5
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

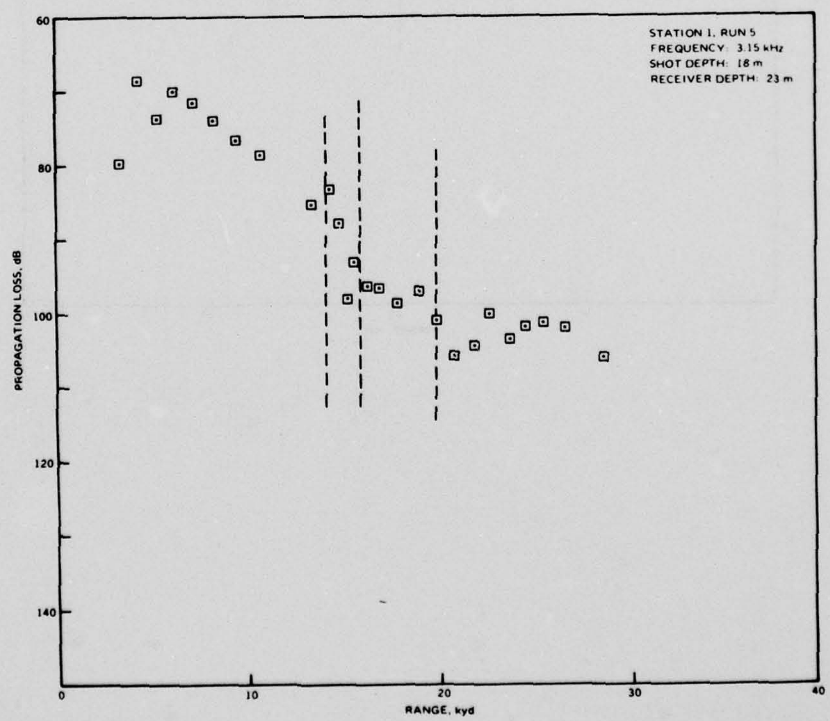

STATION 1, RUN 5
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

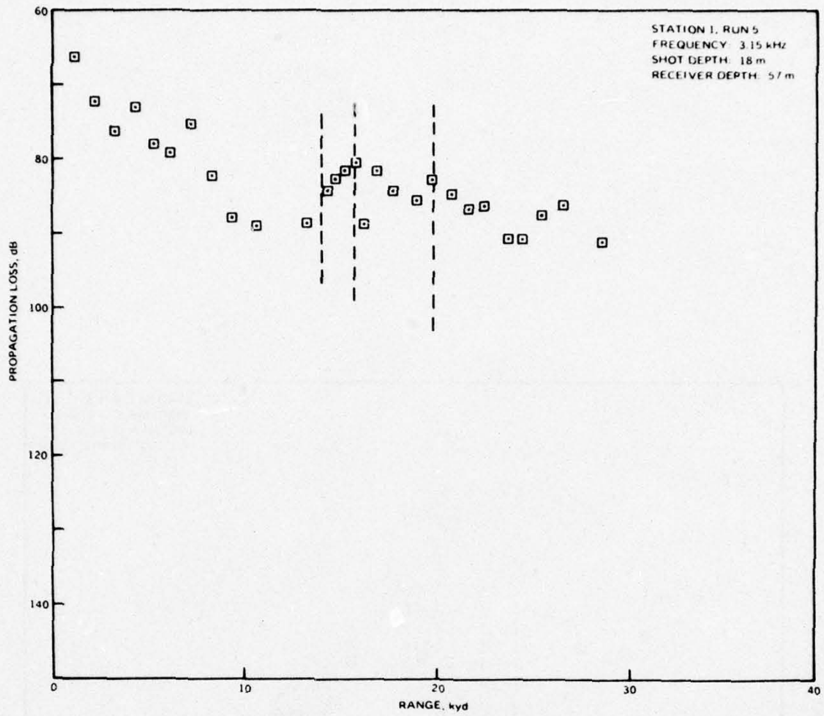

STATION 1, RUN 5
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 95 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

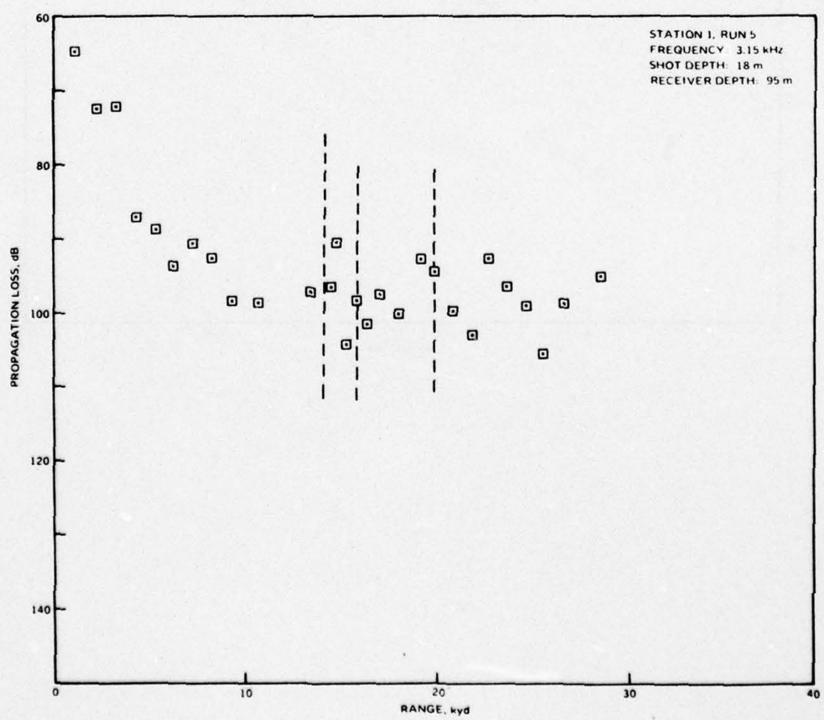


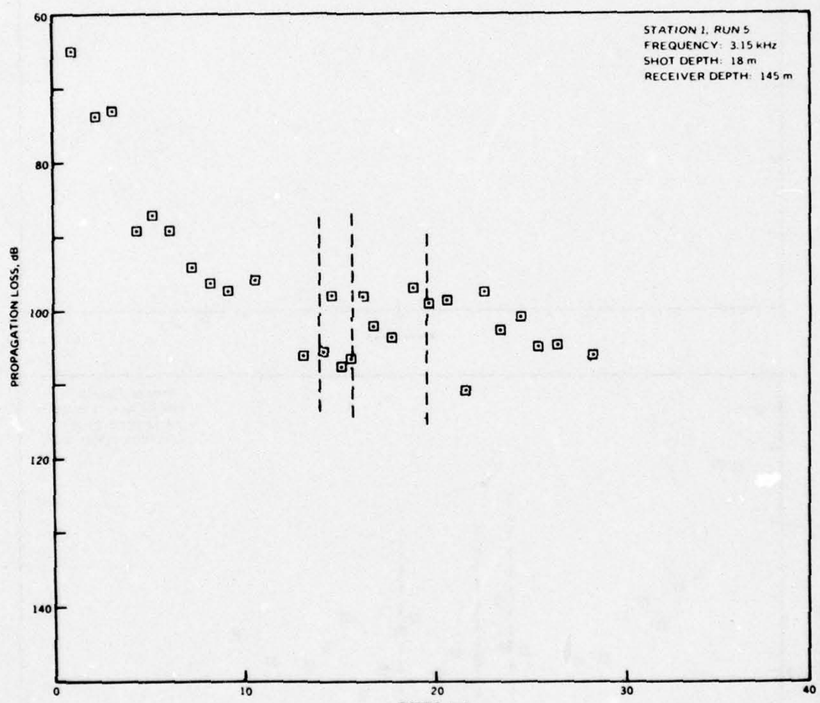
STATION 1, RUN 5
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd


STATION 1, RUN 5
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION 1, RUN 5
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION 1, RUN 5
FREQUENCY 3.15 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 57 m
PROPAGATION LOSS, dB
RANGE, kyd

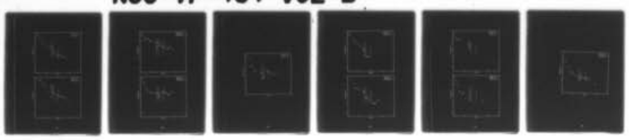

STATION 1, RUN 5
FREQUENCY 3.15 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 95 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION 1, RUN 5
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40

AD-A049 079 NAVAL UNDERSEA CENTER SAN DIEGO CALIF F/G 20/1
SURFACE-DUCT SONAR MEASUREMENTS (SUDS I - 1972) PROPAGATION LOS--ETC(U)
APR 76 E R ANDERSON

UNCLASSIFIED NUC-TP-464-VOL-2 NL

2 OF 2
AD
A049079



END
DATE
FILMED
3-78
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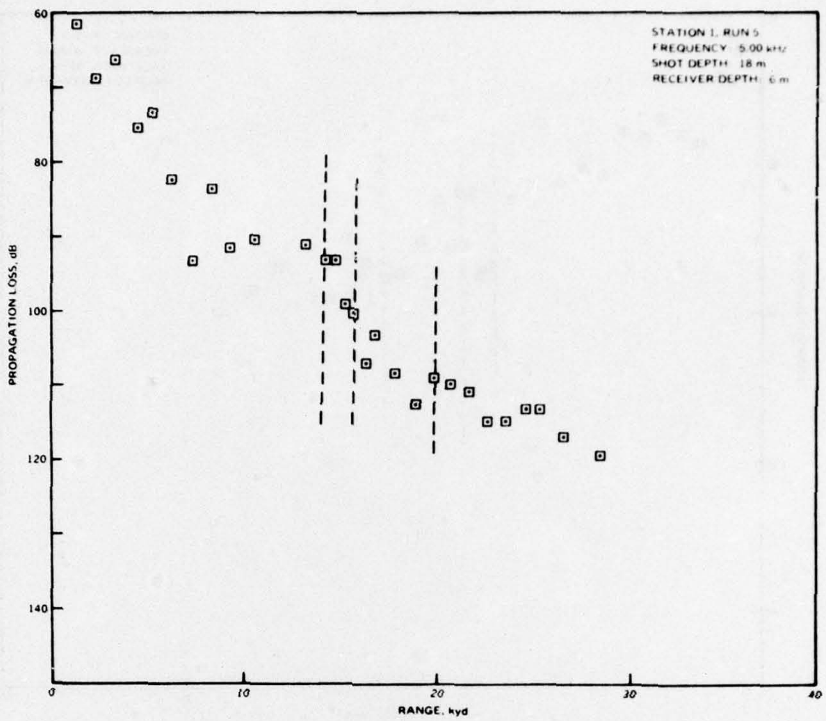
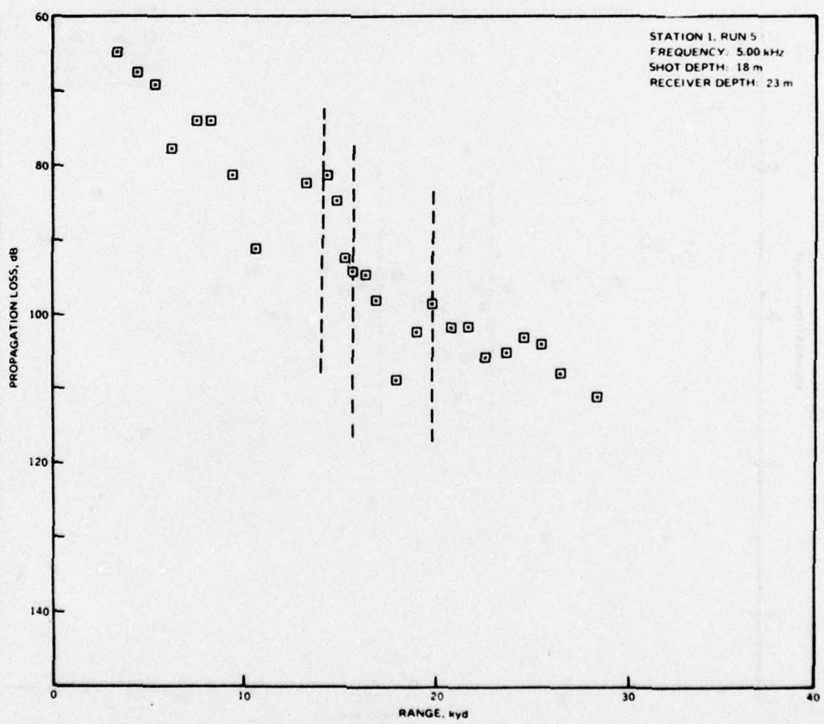
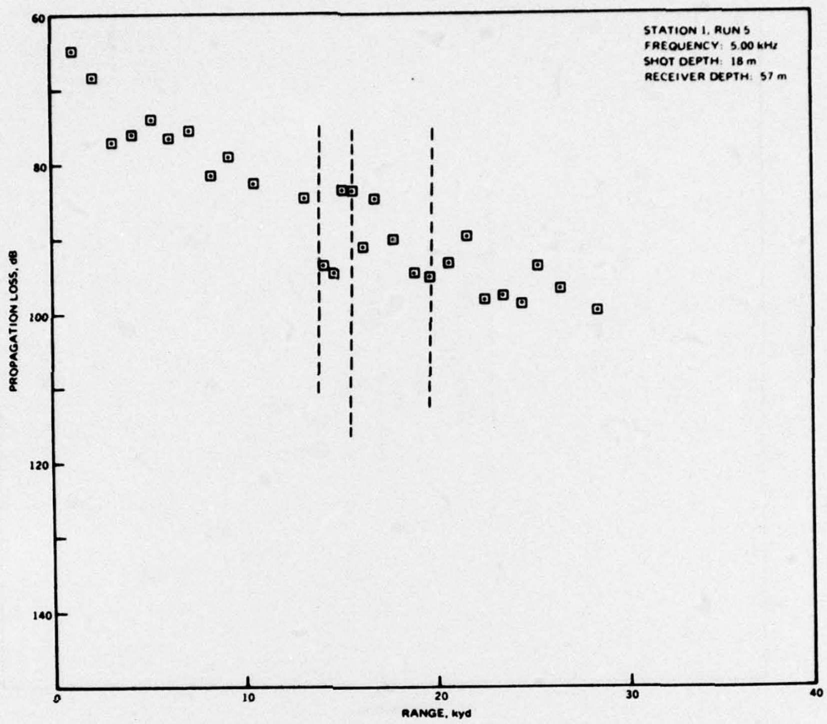
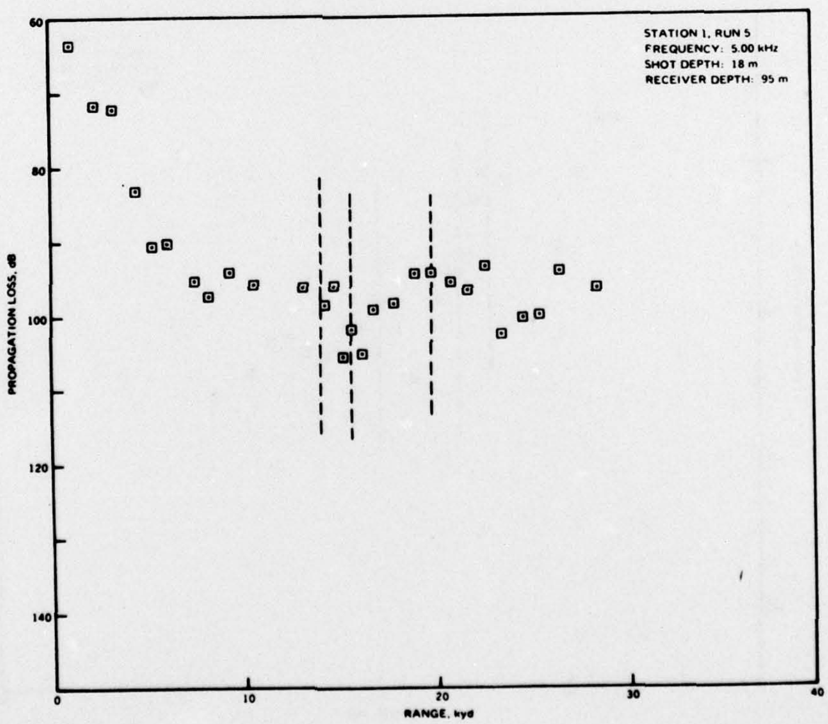
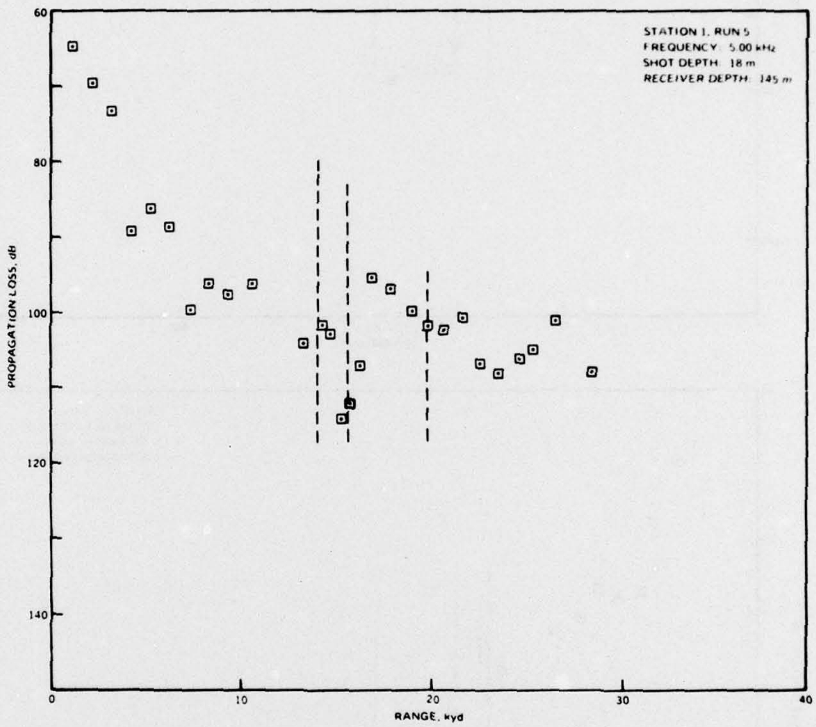
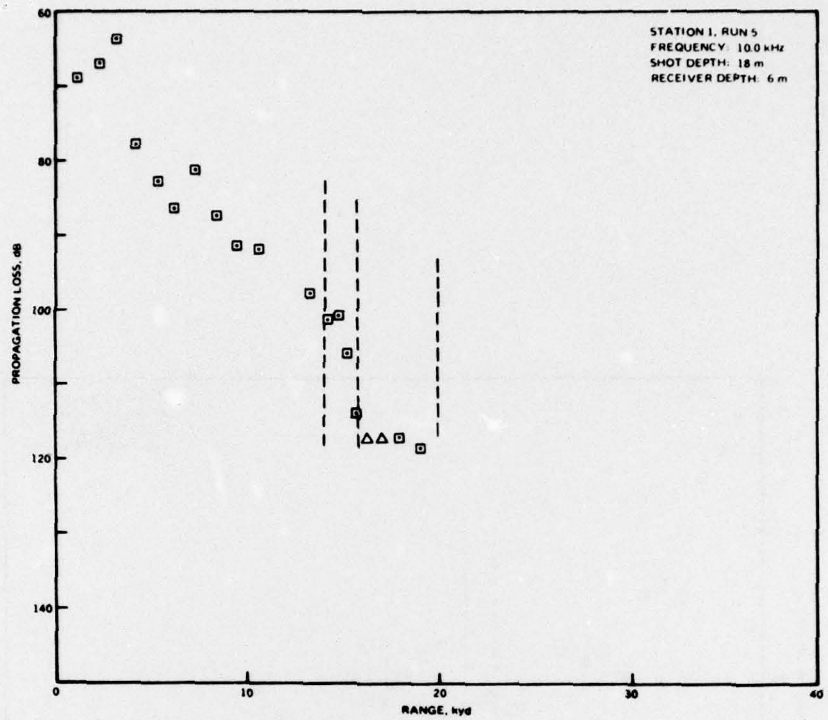

STATION 1, RUN 5
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

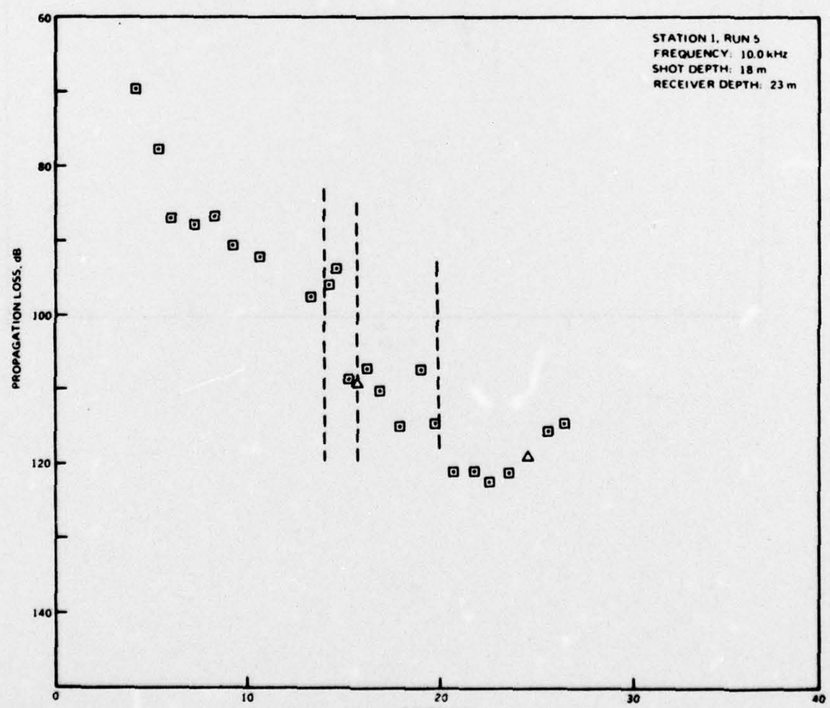

STATION 1, RUN 5
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

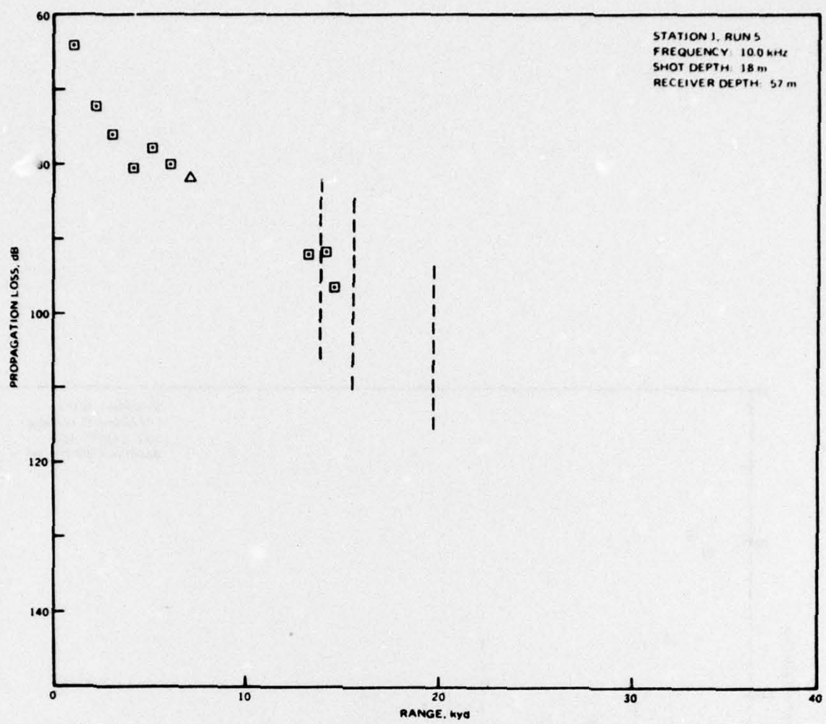

STATION 1, RUN 5
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

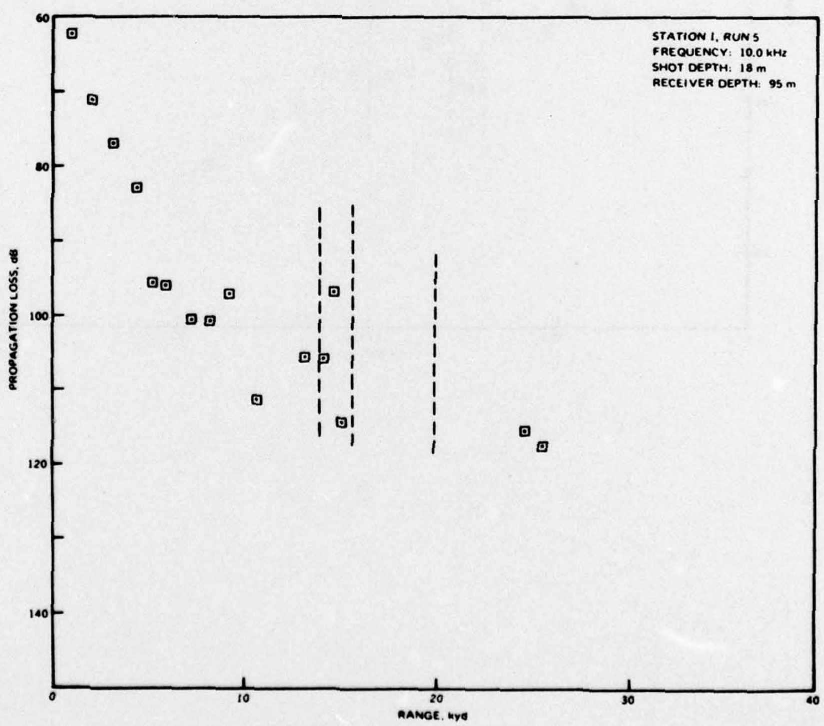

STATION 1, RUN 5
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 95 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

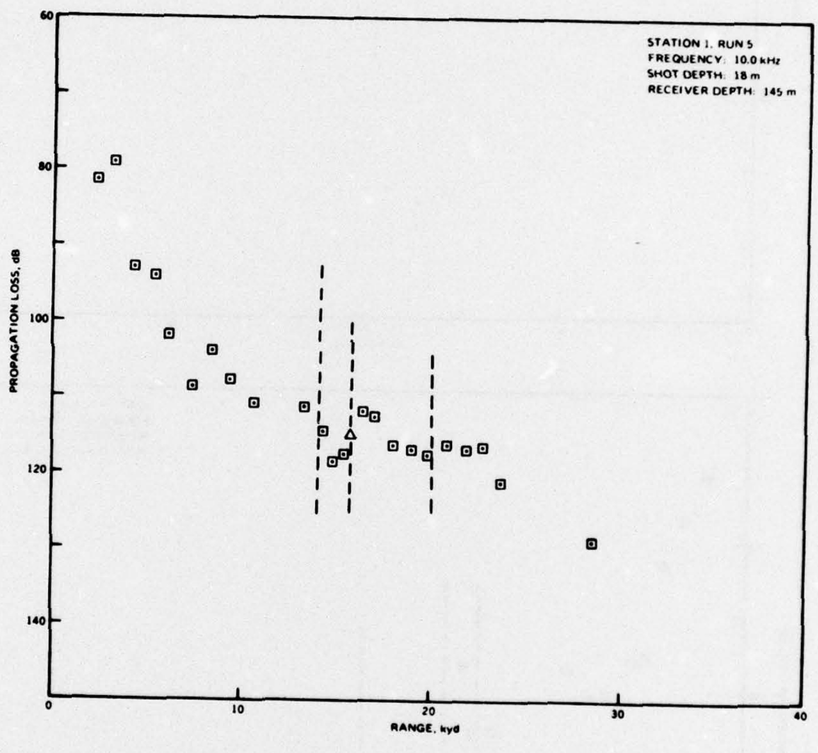

STATION 1, RUN 5
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40


STATION 1, RUN 5
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION 1, RUN 5
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 23 m
PROPAGATION LOSS, dB
RANGE, kyd


STATION J, RUN 5
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 57 m
PROPAGATION LOSS, dB
RANGE, kyd
60
100
120
140
0
10
20
30
40


STATION J, RUN 5
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 95 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40


STATION 1, RUN 5
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 145 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40